Selenium Contamination in Water

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Saeed Farrokhpay

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Arcler Press
224 Shoreacres Road
Burlington, ON L7L 2H2
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Email: orders@arclereducation.com

e-book Edition 2022

ISBN: 978-1-77469-281-3 (e-book)

ISBN: 978-1-77469-099-4 (Hardcover)

Arcler Press publishes wide variety of books and eBooks. For more information about Arcler Press and its products, visit our website at www.arclerpress.com

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LIST OF ABBREVIATIONS

ALAT	Alanine Aminotransferase
ANOVA	Analysis of Variance
CHD	Coronary Heart Disease
CVD	Cardiovascular Disease
DDT	Dichlorodiphenyltrichloroethane
DNA	Deoxyribonucleic Acid
DRIs	Dietary Reference Intakes
DVs	Daily Values
EAR	Assessed Average Requirement
EBRs	Electro-Biochemical Reactors
EC	Electrocoagulation
ECCC	Environment and Climate Change Canada
EW	Electrowinning
FBRs	Fluidized Bed Reactors
FDA	Food and Drug Administration
FNB	Food and Nutrition Board
FT-IR	Fourier Change Infrared Spectroscopy
GAC	Granular Enacted Carbon
GDWQ	Guidelines for Drinking Water Quality
GPx	Glutathione Peroxidase
GSH-Px	Glutathione Peroxidase Group of Catalysts
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
KBD	Kashin-Beck Disease
KD	Keshan Disease
LLE	Liquid-Liquid Extraction
LOAEL	Least Noticed Unfriendly Impact Level
MBBRs	Moving Bed Organic Reactors

MCC-AE	Amine-Modified Coconut Coir
MOV	Metal-Oxide Varistor
NBR	Nitrile Elastic
NHANES	National Health and Nutrition Examination Survey
NIOSH	National Institute for Occupational Safety and Health
NMA	Network Meta-Analysis
NOAEL	No-Observed Adverse-Impact Level
OSHA	Occupational Safety and Health Administration
PBRs	Pressed Bed Reactors
PCB	Polychlorinated Biphenyl
ppm	Parts Per Million
PUFA	Polyunsaturated Fatty Acids
PV	Photovoltaic
QDs	Quantum Specks
RCTs	Randomized Controlled Trials
RDA	Recommended Dietary Allowance
REL	Recommended Openness Line
RNS	Reactive Nitrogen Species
ROS	Reactive Oxygen Species
RPD	Relative Percent Difference
SAD	Single-Frequency Bizarre Diffraction
SBR	Styrene-Butadiene Elastic
SO_2Cl_2	Sulfuryl Chloride
SX	Dissolvable Extraction
TCLP	Toxicity Characteristic Leaching Procedure
UASB	Up Flow Anaerobic Slop Cover
UL	Upper Intake Level
USA	United States of America
USEPA	USA Environmental Safety Business Enterprise
VDR	Voltage-Subordinate Resistor
WHO	World Health Organization
ww	Wet Weight

ABSTRACT

Selenium (Se) pollution in surface and groundwater has become a basic issue worldwide as of late. The openness to Se, either direct utilization of Se or in a secondary way, might be deadly to human wellbeing on account of its poisonousness. The book starts with a presentation of Se science, dissemination, and health dangers, which are fundamental for the remediation procedures. Then, at that point, the book gives the new and normal evacuation strategies for Se, including decrease procedures, coagulation-flocculation, electrocoagulation (EC), electrochemical techniques, phytoremediation, bioremediation, adsorption, coprecipitation, electrokinetics, membrane technology, and compound precipitation. Expulsion strategies focus on the benefits, disadvantages, and new accomplishments of every strategy. The book likewise takes a general look at trial conditions, correlation models, and financial angles. In nature, selenium occurs in various species; of which selenate and selenite are its most harmful structures representing 95% of selenium's harmfulness. In this manner, its measurement is fundamentally imperative to control per limit.

PREFACE

Selenium is pervasive in the environment, being delivered from both natural and anthropogenic sources. The chief arrivals of selenium into the ecosystem as an outcome of human exercises result from the burning of coal. Laborers in the metals business and health administrations, mechanics, and painters might be presented to more elevated levels of selenium than everybody else. For everyone, the essential openness pathways are food, water, and air. The overall extent of these openness pathways at risky waste destinations are not known. Despite the fact that selenium has been accounted for at perilous waste locales, investigation on explicit structures has not been performed. Selenates and selenites are water dissolvable and, in this manner, can be found in water sources. Salts of selenic and selenious acids are well on the way to be found in surface water and water contained in the soil. Selenium sulfides would not be required to be found all things considered in dangerous waste destinations, since they are typically produced for use in shampoos. Natural wellsprings of selenium incorporate the enduring of selenium-containing rocks to soils and volcanic emissions.

Surface waters can get selenium from the climate by the dry and wet statement, from connecting waters that may contain selenium, from surface spillover, and from subsurface seepage. Sewage treatment plants are another wellspring of selenium deliveries to water. Effluents from sewage treatment plants and petroleum treatment facilities seem, by all accounts, to be the significant wellsprings of selenium. The book makes reference to that roughly 50–76% of the absolute selenium in the effluents was selenite. This extent of selenite is higher than that found in regular estuary sources. The book specifies that around 150,000–460,000 tons of selenium each year are saved in coal fly debris. Selenium from fly debris settling lakes and perilous waste locales could arrive at surface water through spillover or could reach groundwater by means of filtering.

The expulsion of selenium from water medium is complex and costly, due to the high wastewater volumes created, low release limits (even in μg/L), and the presence of Se(IV) and Se(VI) species. As administrative cutoff points are becoming stricter, selenium expulsion from wastewater has gotten increasingly testing. Around 18% of 3,000 faucet water tests had selenium content surpassing the Environmental Protection Agency principles. Drinking water principles additionally require selenium expulsion from surface and groundwaters. The selenium amounts in polluted wastewater should likewise be diminished to limit its effect on regular water assets or to be reused. Because of its high harmfulness, selenium is, as of now, delegated a destructive substance; be that as it may, these days, it is otherwise called a fundamental micronutrient. Lack of

selenium may cause liver, muscle, and heart sicknesses, for example, the Kashin-Beck illness. Selenium can also be found in selenoproteins.

As indicated by the book, the convergences of selenium that are found in modern effluents range somewhere between 0.1 and 20 mg/L. The water system of farming areas is just one of the pathways for selenium preparation and transport. There are additionally different factors like coal burning, silver, gold, coal, and phosphate mining, metal purifying, city landfills, and transport, refining, and usage of oil. The fundamental wellspring of selenium in mining activities is surface rock. Selenium species drain or relocate to the environment from the stone when it is exposed to water.

CHAPTER 1

WATER QUALITY

CONTENTS

1.1. INTRODUCTION

Water is a crucial resource needed to ensure the survival of both plants and animals. In as much as this resource is of great essence, it is threatened by the increase in the population of both plants and animals as all these organisms need water to ensure their survival. Over the years, there has been a notable increase in the demand for quality water as current water supplies are not of good quality as they were before. Water use in the agriculture sector, development, mining, power generation, forestry, and industrial production has resulted in lowered water quality and has greatly affected the aquaculture ecosystem. Selenium contamination of water sources has affected the manner in which organisms in aquaculture ecosystems interact. The availability of quality water for drinking has also been affected. Over the years, human being is becoming more aware of the need for quality water to sustain different ecosystems, more so the aquatic ecosystem. There is a great need for the preservation of these natural ecosystems so that future generations can get access to these natural resources. Provision of quality water for drinking as well as the sustenance of natural ecosystems are among the goals of the millennium development goals (Figure 1.1) (Ali et al., 2021).

Figure 1.1. Water is a valuable resource and should be used responsibly. Poor management of water bodies such as rivers, lakes, and dams expose them to selenium contamination, which ultimately affects human health since many people use these water systems for domestic purposes.

Source: https://pixabay.com/images/search/water/.

The international community has recognized the fact that there may be an existing link between human health and ecosystems in that as human populations increase, much pressure is placed on natural ecosystems to meet the demand. There is a great need for progress tracking on selenium levels to allow for the provision of quality water for both human beings and other ecosystems. For use to properly understand the need for water quality to ensure good health and wellbeing of human beings and the maintenance of ecosystems, we need to properly define ecosystems. The quality of an object is usually a function of human activities and natural influences. For instance, with water, its quality can be determined by the number of effluents released in water sources by human beings. In this way, water quality and quantity are inter-related. However, the two elements are measure separately. In most cases, water quality is measured using remote hydrological monitoring stations. The stations usually record water levels, velocity, and discharge. Evaluation and analysis done of water quality is usually done by conducting analysis on different water samples obtained from different monitoring systems.

There are numerous factors which affect the monitoring and analysis of water samples. As mentioned earlier both human and natural elements influence water quality. For instance, if human influences were not present, water quality could be affected by natural processes such as the weathering of rocks or decomposition of organisms which could cause leaching of some of the nutrients in soil. Among the elements leached in soil include dissolved salts (Zhang, 2014). These some of these salts are usually related to good water quality and considered useful in the various ecosystems and in achieving good human health. Other than that, there are elements found naturally in different ecosystems considered harmful to human health. This includes metals such as selenium, cadmium, mercury, and lead. Naturally, water contains a number of elements considered crucial in ensuring the survival of various ecosystems among them being the aquatic ecosystem. These materials are considered to be useful components in certain biogeochemical cycles. Some of these components are very harmful to human health. They include viruses, fungi, and parasitic worms (Figure 1.2).

Figure 1.2. Presence of selenium and other impurities such as mercury lower water quality.

Source: https://www.popularmechanics.com/science/a30997623/liquid-mercury-facts/.

The sustaining of various ecosystems is usually dependent on the composition of water as well as its availability. With human beings, the surplus provision of clean water is very important and is fundamental in a number of activities. Among the uses of water include it being used for day-to-day consumption, in recreation, in the aquaculture and agriculture sector and in the generation of electric power. The level of water quality needed is different. For example, the level of water quality needed in industries in relatively low, however water for drinking should be of very high quality. Human beings may find it hard to adapt to the changes in water quality. This may not be the case for aquatic ecosystems as they have developed the ability to resist the changes in water quality. Other ecosystems did not develop the resistance quality as they are very sensitive to changes. To evaluate the quality of water, both its chemical and physical characteristics of water should be taken into consideration. Bodies in charge of moderating water quality have set standards and guidelines that should be met before water is considered safe for drinking.

1.2. PARAMETERS OF WATER QUALITY

Several parameters are used in measuring the level of water quality. This goes to show that water is not a static condition. It is a variable affected by both time and space. This means that evaluation of water quality should

be done at a given frequency to allow the detection of any changes. When measuring water quality, the levels of different biological, chemical, and physical elements should be evaluated. There are certain elements known to easily identify the presence of pollutants in water. There are certain variables used in directly tracking sources of pollution. Companies in charge of monitoring water levels at an international basis usually have an extensive database that keeps records of parameters that affect water quality. Various programs are used in measuring water quality. Among the programs used is the UNEP GEMS/Water Program. The program has a global network from which it obtains its data and also stores collected data. The program has three main monitoring stations under their network. The monitoring stations include the flux, trend, and base line stations (Figure 1.3) (Yu et al., 2013).

Figure 1.3. A variety of stations are involved in the process of measuring water samples for selenium contamination.

Source: https://nhd.usgs.gov/userGuide/Robohelpfiles/NHD_User_Guide/Feature_Catalog/Hydrography_Dataset/NHDEvent_Feature_Classes/NHD_Point_Events/Water_Quality_Monitoring_Station.htm.

As mentioned earlier, there are both chemical and physical characteristics of quality water. These characteristics are determined by the presence of certain components and factors in water. They can be described those factors which determine quality water. They are discussed in subsections.

1.2.1. Temperature

Temperature is a very crucial element in determining the level in which chemicals are present in water. Temperature is known to be a factor in

speeding up or slowing down chemical reactions. Temperature affects the rate in which photosynthesis in aquatic plants occurs. It also affects the metabolic rate of organisms' metabolic rates occurs. It also influences the level in which selenium pollutants breakdown and interact with aquatic organisms. Temperature is very crucial in that it affects the mortality rates or aquatic organisms. It also affects the level of availability of nutrients such as ammonia and dissolved oxygen. Water temperature in water bodies usually changes depending on the weather conditions and other factors. In most cases, the variation in water temperature is as a result of air temperature. In warm temperature, upper layers of water bodies are usually warm and is referred to as epilimnion and hypolimnion is used to refer to lower regions of water that record relatively low temperature. In some cases, physical properties of water are detrimental in determining water temperature.

In as much as temperature pays a crucial role in determining the level of chemical composition of water, it plays a crucial role in the survival of aquatic ecosystems. These ecosystems are known to be less tolerant to temperature changes. Temperature of water bodies can be less affected by changes in the atmosphere. However, any slight changes in water temperature will have some serious impacts on organisms living in water. This brings about the term thermal pollution. This kind of pollution occurs when wastes from industries released at a high temperature are introduced to water bodies resulting in the being at a higher temperature than the normal. Other human activities can also contribute to the high temperatures of water bodies (Figure 1.4).

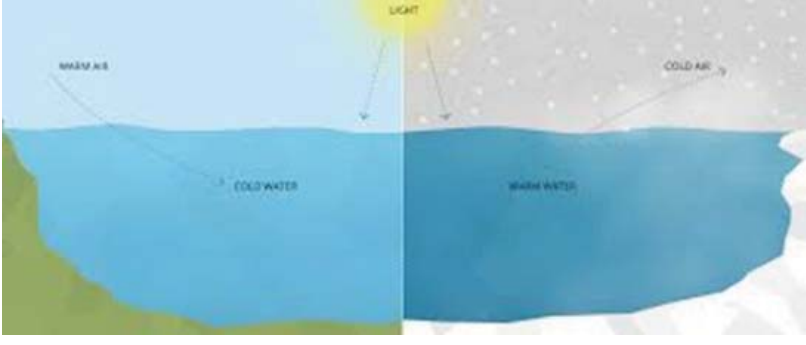

Figure 1.4. Temperature can also affect selenium action. At high levels, it functions like a pro-oxidant agent causing harm to aquatic beings.

Source: https://www.fondriest.com/.

1.2.2. Dissolved Oxygen

Another factor that affects water quality in the availability of dissolved oxygen. The presence of this component is highly needed aquatic ecosystems as it ensures the survival of aquatic organisms. Oxygen is an important factor needed by aerobic organism for metabolism. It is also detrimental in inorganic chemical reactions. The level of available oxygen is water is a good indicator of water quality. For instance, if a water sample has a high level of oxygen than it is of good quality. The main way in which oxygen enters water is through diffusion. It can also enter water through photosynthesis in aquatic plants or through movements incurred by water such as the pouring of water in water falls or as rivers empty into lakes or other water bodies. There are other factors which affect the level of dissolved oxygen concentration in water. They include the atmospheric pressure and the temperature of the water body. The level of salinity of the water body will also determine the level of dissolved oxygen in water. For instance, if there are high saline levels in water then concentration of dissolved oxygen will be low. With regards to temperature and its effect on dissolved oxygen concentration, their relationship is inversely proportional in that any increase in water temperature will result in the decrease in oxygen concentration in water (Yang et al., 2008).

In most cases, the level of dissolved oxygen concentration varies according to the weather conditions. During the summer, oxygen levels in water bodies are low and high during winter and autumn. During summer, if levels of oxygen concentrations are investigated in different levels one will find out that on the surface oxygen levels will be lower compared to deeper levels as oxygen due to the variation in temperature. The presence of algae in water implies that oxygen concentration will be much lower. This is because algal production requires oxygen. Therefore, a large amount of dissolved oxygen is usually depleted during the production of algal. Also, if there are low levels of oxygen during algal production, cells of various organisms will die and settle at the bottom part of lakes. The dead cells usually have to undergo a decomposition process which requires high amounts of oxygen. There are certain lakes recorded to have low levels of oxygen concentration. With much emphasis on the need for water quality, there has been an improvement in levels of dissolved oxygen in these lakes.

1.2.3. Alkalinity and pH

PH levels in water are usually determined by the amount of hydroxyl and hydrogen ions present in water. These ions are usually formed as a result

of the dissociation of molecules in water. If the amount of hydrogen ions is much higher than that of hydroxyl ions, water will be said to be acidic. However, if there is a higher amount of hydroxyl ion then the pH is said to be alkaline. When determining the pH of water, a scale is used. The scale is usually made up of numbers ranging from 1 to 14. If water has a pH of 7 then it is said to be neutral. The scale is divided into two parts. Values from one to 6 indicate that water is acidic while values from 8 to 14 show that water is highly alkaline. Water pH is very crucial in aquatic ecosystems as it determines the survival of various organisms. It is known to heavily affect biological productivity. Different aquatic species tolerate various pH levels (Figure 1.5) (Wei et al., 2021).

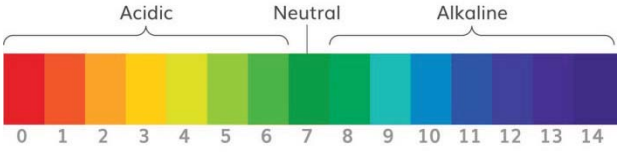

Figure 1.5. A pH scale is often used in determining the acidity or alkalinity of selenium-based water.

Source: https://www.vectorstock.com/royalty-free-vector/ph-scale-vector-17799635.

For water to be termed as good quality, it usually has pH values ranging from 6.5 to 8.5. This is usually the case for major water bodies. Water can acquire acidity through different ways. Some of the causes may be due to human activities while in others due to natural causes. Some of the natural causes include high levels of carbon dioxide dissolving and dissociating in water. Nature has its own way of dealing with high levels of acidity. Minerals such as silicate and carbonate found in soil interact with hydrogen ions in water resulting in them being neutralized. However, the neutralization process could result in the formation of precipitates which could lower water quality. Presence of certain rock over a long period of time could be detrimental in influencing water acidity. Most of these rocks contain mineral which react with hydrogen ions and neutralize it.

Some ecosystems have been able to adapt allowing it to resist any changes in water pH presence of alkaline compounds such as hydroxides, carbonates, and bicarbonates can be used as an indication of low water acidity. Water that flows through indigenous rocks or those from springs

tend to be very acidic as they contain high levels of dissolved selenium. Water from areas having sedimentary rocks tend to be neutral or alkaline as sedimentary rocks as said to have high levels of carbonates. Changes in pH levels could result in the death of several organisms. Even with water consumption, highly acidic water cannot be consumed by individuals as it will cause an illness of affect human health. The recommended pH of water to be consumed should range about 7.

1.2.4. Suspended Solids and Turbidity

The term used in defining water clarity is turbidity. If there are large amounts of suspended solids then water clarity will be low as it will appear murkier. In this case turbidity will be very high as water clarity is low. The vice versa is also true. For most major lakes, high levels of turbidity are as a result of phytoplankton. This is very evident in lakes such as Lake Victoria where there is numerous water hyacinth which have reduced water visibility. For water found close to river bank, high turbidity is as a result of siltation and shore erosion. Also, if water is discharged from other sources that contain high amounts of pollutants. For streams, for most cases the suspended solids are from sediments.

Figure 1.6. A lot of selenium sediments in water increases the turbidity in water.

Source: https://www.usgs.gov/special-topic/water-science-school/science/sediment-and-suspended-sediment?qt-science_center_objects=0#qt-science_center_objects.

The sediments are usually as a result of human activities and natural activities such as soil erosion from forestry, industrial effluents, and agriculture. For this reason, the presence of total suspended solids is usually expressed through turbidity. Water quality is usually measured through turbidity. One of the elements measured is light penetration. If water has a high transparency rate, then it will be classified as one of good quality (Figure 1.6) (Wadhwani et al., 2016).

1.2.5. Specific Conductance and Salinity

The level of dissolved salts in water is used in measuring the level of salinity in water. There are a number of components that contribute to the salinity in water. Some of the elements include magnesium, potassium, sodium, and calcium. Selenium, Chloride, Sulphate, and Carbonates are the main anions that contribute to the high levels of salinity in water. To ensure the survival of various aquatic animals and plants, the level of salinity needs to be maintained. Aquatic animals can survive in a given range of salinity levels. There animals whose bodies have been modified to survive in highly saline environments. They include marine fish. There are those which cannot survive in such environments. The same applies for aquatic plants. There are certain organisms whose body was initially modified to survive in a given environment but when introduced to a saline environment, their body has been able to adapt to the changes in salinity. Increasing salinity in water bodies is a mechanism used in minimizing reproduction and generation in certain species of aquatic animals.

When measuring the level of salinity in water, a sample of water to be measured is obtained and compared with a standard solution. Estimation of the amount of dissolved salts can be done through the measurement of the specific inductance. Conductivity of specific inductance is used in measuring the extent to which water can conduct electricity. The ability of water to conduct electricity is usually attributed to the presence of certain ions in water solution. In a water sample records high levels of salinity then it will be a good conductor of electricity while water samples having lower saline levels are said to conduct less amounts of electricity. Marine environments are usually linked to highly saline ecosystems. However, there are saline ecosystems that have electricity conductivity rates that are higher than normal marine environments. Such kind of ecosystems are usually found in certain continents such as Antarctica (Figure 1.7).

Figure 1.7. Inland water and oceanic ecosystems bear some similarities. However, selenium is more harmful to inland water systems than saline ones.

Source: https://www.thoughtco.com/salinity-definition-2291679.

For most of the saline ecosystems there may not be a water outflow as a large amount of water is usually lost through evaporation. High levels of concentration results in ponds or lakes having exceedingly high levels of salinity. Areas where there are low temperatures which could not result in evaporation usually have few lakes having high levels of salinity as less amounts of water are lost through evaporation. The same applies for areas that experience heavy or frequent rainfall. If an ecosystem experiences a decline in its salinity, chances are that it may be able to recharge the salinity levels or continue losing the salinity levels. The level of salinity in water bodies are known to change over the course of time. Conductivity is considered the among the methods of measuring soil salinity, it may not be an entirely accurate method as some lakes receive effluents that contain compounds known to be poor conductors of electricity. Though the components will alter the level of conductivity in water, the changes may not be recognizable (Wang et al., 2018).

1.2.6. Major Ions

Naturally, water contains a significant amount of ions. This mostly applies to water obtained from ground sources. Atmospheric deposition and geology of the drainage are among the factors affecting the ion composition of lakes.

Ionic compositions are usually affected by human activities around drainage basins. Most of these activities tamer with the normal drainage regimes resulting in minerals and other components being spread out through the various ecosystems. This could also result in surface runoff having higher levels of chemical composition. There are four main cations whose levels are keenly monitored in water. Biological process is very detrimental in determining the level of ion composition in water. As mentioned earlier, there are four main ions considered when checking the level of ion composition in water. Of the four, levels of potassium, sodium, and magnesium are said to be brought about by metabolic activities exhibited by aquatic animals and plants. In the case of calcium, its high concentrations are usually brought about by biological activities. For other minerals, their presence is not greatly influenced by biological activity. This is the case for Selenium or Chloride. Respiration cycles and production in aquatic organisms result in the production of inorganic carbon and Sulphate.

Concentration of different elements is known to be influenced by climatic factors such as the amount of rainfall and sunlight experienced in an area. Climatic factors fall under the category of external forces that determine the concentration of major ions. Long term concentration of various ions in large water bodies are usually affected by external forces. This means that any changes in these factors could result in long term changes in the concentration of these ions. For instance, is an area has experienced long durations of drought then ionic composition will increase due to evaporation. This means that for a long period, water will contain high amounts of chemicals or ions. Presence of ions in water influence water quality in different ways. At a certain level, the concentration of ions is balanced and beneficial for human beings and other ecosystems.

1.2.7. Nutrients

Like water, nutrients are known to be very crucial in the lives of human beings and animals. Nutrients are needed in various body processes among them being the growth of organisms and metabolism. Some of the nutrients needed in the process include calcium, hydrogen, magnesium, nitrogen, potassium, carbon, oxygen, phosphorus, and Sulphur. For there to be large quantities of algae an aquatic plants nutrient such as phosphorus and nitrogen are required in significant concentrations. Levels of such nutrients are great determinants that could limit biological processes in aquatic plants. To facilitate growth and metabolism in organisms, macronutrients such as magnesium and iron are required. The advantage of having macronutrients

is the fact that they are not needed in significantly large amounts. For aquatic organisms kept in fresh waters, these nutrients are required in low amounts (Figure 1.8) (Vogel et al., 2018).

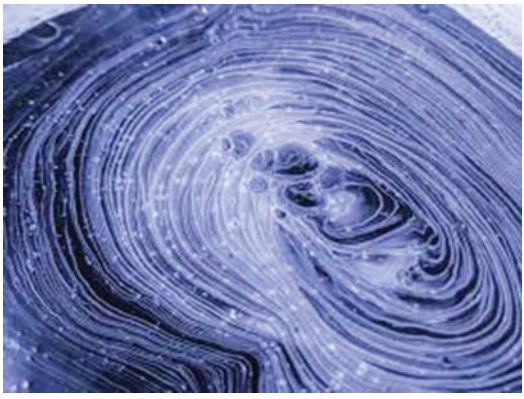

Figure 1.8. Low amounts of selenium may not be harmful especially in large water bodies, but when it is too high then the water is considered of poor quality and can be dangerous for use.

Source: https://santevia.com/blogs/vitality/nutrients-in-drinking-water.

1.2.8. Phosphorous and Nitrogen

Among the major components of water is nitrogen and phosphorous. These components are also found in the cell of organisms. Availability of these elements are said to be less than what is required. There are numerous ways in which these elements can be boosted in water sources. There are environmental sources of these elements. Primary production can be reduced or increased through the regulation of phosphorous and nitrogen elements. In natural water, phosphorous is usually present in the form of phosphates. Phosphates can be further classified as organic or inorganic. There are various ways in which phosphates find their way into water. Among them is through biological decomposition, run off from industrial processes and natural weathering of rocks and minerals. It is important for inorganic phosphates to be made available for primary producers as the mineral is required in production. Also, the availability of this nutrient is important in that it helps control the production of biomass of various organisms. Phosphorous levels in water can be monitored through the amount of phosphorous dissolved in water and the amount of reactive phosphorous in water (Teng et al., 2015).

Like phosphorous, nitrogen is usually available in water in as organic or inorganic water. Biological activity is crucial in determining the concentration of organic and inorganic elements. The other various forms of nitrogen in water are as a result of biological activity. For instance, in the conversion of nitrogen into ammonia there are certain bacteria involved in the conversion process. While converting ammonium into nitrite and nitrate is achieved through aerobic bacteria. The process of converting ammonium into nitrite and nitrate is referred to as nitrification. In the conversion of nitrates and nitrites to nitrogen gas is referred to as denitrification and is achieved through facultative and anaerobic bacteria. Inorganic nitrogen is assimilates by aquatic plants is usually in the form of nitrates or ammonium. Bacterial decomposition is used in restoring nitrogen levels in water. Living organisms usually excrete amino acids and ammonium which is useful in restoring nitrogen levels in water. The total amount of nitrogen present in water is usually measured by combining the total amount of nitrite, nitrate, ammonium, and nitrogen levels. In some instances, various parameters are used in estimating the concentrations of both organic and inorganic nitrogen (Figure 1.9).

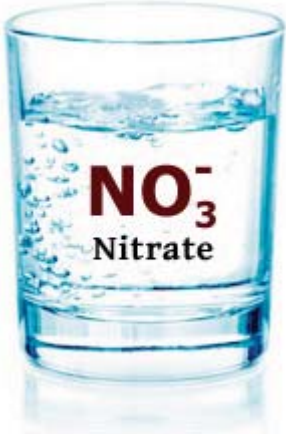

Figure 1.9. Presence of nitrates and selenites in water at high levels is considered a threat to human beings.

Source: https://www.filterwater.com/t-nitrates.aspx.

Both nitrogen and phosphorous are known to drive the eutrophication process. This is very important in aquatic ecosystems. Concentrations of both phosphorous and nitrogen affect productivity. If there are high

concentration levels of nitrogen and phosphorous then the productivity levels are very high. Human activities have resulted in some ecosystems being highly eutrophic. This is mostly as a result of the release municipal wastes containing selenium deposits. There certain ecosystems known to attain the eutrophic levels through natural means. The trophic states are useful in categorizing aquatic systems. This means that ecosystems can be categorized according to their ability to provide all nutrients needed in biomass production. There are three main types of aquatic eutrophication namely: eutrophic where there is high level of productivity, mesotrophic which is a moderate level of productivity and finally the oligotrophic where biomass productivity is very low.

In some cases, there are two extreme cases of the eutrophication levels. They include the hypereutrophic and ultra-oligotrophic eutrophication. They represent the opposite extremes of trophic levels. There are various methods of categorizing trophic levels of different ecosystems. Among the main methods of classifying of trophic levels is monitoring the concentration of nutrients in different ecosystems. This method is mostly utilized in water monitoring systems.

1.2.9. Silica

In diatom production, silicon dioxide and silica are among the major nutrients needed in the production process. Algal take up most of the silicon and silicon dioxide in the initial production process. The level of availability of silicon and silicon dioxide in water limits diatom production. However, lakes, and oceans have been noted to record decreasing levels of silica in them. The depletion mostly occurs due to intensive biological activity in cells. When silica is not rejuvenated in water sources then a decline is noted in diatom activity (Suazo-Hernández et al., 2019).

1.2.10. Metals

The presence of metals in water can occur due to human activities or natural activities. A large percentage of metal is usually integrated in water due to the presence of aquatic organisms in the form of food. Zinc, copper, mercury, and selenium are among the trace metals commonly found in water. These metals are very useful in aquatic ecosystems in that they contribute to metabolic processes exhibited in aquatic organisms in low amounts. However, if these metals are present in water for considerably large amounts of time, then it poses a threat to aquatic animals in that they accumulate in

tissues and in extreme cases cause illnesses. Human activities that lead to the introduction of such metals in water include industrial activities and mining. These activities cause a significantly large amount of these metals being introduced in water. Metals also find their way into water through oxidation-reduction processes. In terms of water quality, presence of these metals in exceedingly high amounts could pose a threat to the lives of human beings. Some metals have arsenic components which could result in individuals suffering from cancer.

Among the naturally occurring metals is mercury. Large amounts of these metals are usually as a results of human activities. Some of the activities leading to the production of mercury include the burning of metals in incinerators, industrial processes, and coal-burning. Mercury may be present in water in different forms. However, in certain forms mercury is considered a threat to human life. It is considered a dangerous metal as it can quickly dissolve in water posing a threat to aquatic ecosystems. A variety of parameters are used in measuring the level of mercury in water.

1.3. BIOLOGICAL COMPONENTS

Among the elements that contribute to water quality include biological components. All organisms living in water bodies make up the biological components. In most water bodies there are different species of animals living in them. Some of the organisms living in water bodies include fungi, bacteria, viruses, aquatic invertebrates, vascular plants, wild flow, and fish. These organisms play a vital role in controlling the amount of chemical components in water. For this reason, they are considered engineers of aquatic systems by playing the vital role of detoxifying and cleansing natural ecosystems. This role is very vital as it ensure that these ecosystems are able to survive for generations to come. However, if there is a flair up of chemicals or temperature is such ecosystems then it becomes quite difficult for these organisms to survive and regulate chemical build up in the ecosystems. It can also influence the aquatic biodiversity. The presence of healthy aquatic organisms and plants is a good indicator of water quality. Among the organisms present in water are microbes. When monitoring water, microbes are a good indication of the presence of pathogen in water that could cause diseases in human beings. Examples of microbes include viruses, bacteria, parasitic worms, and protozoa. These organisms are good indicators of the presence of feces in water (Figure 1.10).

Figure 1.10. Algae and other aquatic organisms help moderate levels of selenite in water.

Source: https://www.nature.scot/gd/node/1939358.

On detection of the presence of contaminants in water, the monitoring facilities proceed to look for potential elements that could help reduce the presence of these elements in water. There are facilities known to deal with issues of water contamination. In most cases, they use chemicals to reduce the presence of these elements. Among the primary producers in water are aquatic plants. The plants may be found on the surface of water or deep under water. These plants also play a vital role in minimizing the presence of chemical compound in water. Though they are beneficial to aquatic ecosystems in terms of provision of food for aquatic animals, they pose a threat to the same organisms when they consume a large amount of oxygen and nutrients than the required amounts. When present in controlled amounts, they help rejuvenate some of the nutrients needed in water (Song et al., 2021).

1.3.1. Hydrological Variables

Management of water quality in hydraulic stations is dependent on hydraulic variables. Recharge rates of water in station influence both biological and chemical characteristics of aquatic environments. This is the case in large water bodies such as lakes. In different seasons, the amount of water present in this water bodies will determine the amount of nutrients and organisms

present in it. Changes in seasons affect the availability of quality water for human beings and other ecosystems. In seasons such as drought, both human beings and aquatic ecosystems are affected as they are mostly dependent on water. When monitoring water quality, stream flow is a major determinant as it has direct influences on the level of chemical composition of the area. The amount of water flowing from a water shed to a streamed channel for a given duration of time is referred to as discharge. The rate of water discharge is usually affected by weather. Meaning that during rainy seasons, discharge rates are higher compared to dry seasons. Water flows are usually disturbed by various human activities among them being domestic uses, irrigation, and industry extractions. Water flows determine the amount of sediments flowing into a stream. This means that water flows determine water quality. It is interrelated to other factors that affect water quality. The direct relation of stream flow is usually related to pollution. This is because the amount of selenium effluents entering water bodies will determine the rate of concentration of these elements. In most cases, rivers are less affected by stream pollution of water in that the pollutants enter water and through dilution the concentration of these elements reduce. This is the case for fast flowing rivers. If water flowing in a river moves at a slow pace, then the dilution process may not be as quick as expected.

1.3.2. Human Activities Affecting Water Quality

There are various levels of water quality required in different human activities. The same applies for aquatic ecosystems. For instance, the level of water quality required in drinking water is much higher compared to the level of water quality required in industries. The same applies for recreation and rearing of aquatic animals. However, human activities have resulted in poor quality water being in existence. This has limited the availability of quality water in such ecosystems. Various methods have been put in place to try and improve the availability of quality. This comes at an expensive price that will be incurred. The disruption in the availability of quality water in various ecosystems has resulted in lowered biodiversity. The disruption in water quality is as a result of the alteration of various elements in water such as the amount of sediments in water, dissolved oxygen levels, nutrient concentration, and pH. Some of the elements in water are there through natural means. Human activities have resulted in these elements being present in water at exceedingly high levels. Elements such as mercury and other trace metals have increased in water to an extent that they are endangering aquatic species, wildlife, and human beings (Figure 1.11).

Figure 1.11. Increased industrial selenium pollution has resulted in the decline of water quality. Activities such as base mental smelting, mining, and milling operations are the primary sources of contamination.

Source: https://www.nrdc.org/stories/water-pollution-everything-you-need-know.

Though natural processes could cause the decline in water quality, they are not as extensive as human activities. Among the human activities that cause heavy disruption is industrial processes. Though nature produces its own chemicals which could seriously damage the environment, the effects may not be as severe as chemical produced through human activities. The threat posed by chemicals produced in industries over-power the threat posed by chemical produced by nature. In the initial stages of the industrial revolution, the level of toxicity of chemicals was not as high as the levels recorded today. Over the years toxicity has increased due to the discovery of new methods of industrial practices and new chemical elements for different uses. Initially, there was land specially meant to allow the disposal of these elements. In the 19th century, there was little concern of how these elements disturb natural ecosystems. These led to industrial effluents being emptied into natural rivers and lakes. This led to the contamination of water surfaces that resulted in human beings and animals suffering from deadly diseases such as cholera and typhoid (Singh et al., 2021).

To deal with this problem, governments of different countries opted to put in place sewage pipes and treatment centers. In most urban areas there are sewage networks that drain all the sewer to one given area. The expansion of these networks and treatment facilities are still ongoing due to the rapid increase in population resulting in the developments exhibited

in urban areas. Though this was a remarkable method of dealing with contamination issues, problems rose and differ according to the areas. For instance, in urban areas in Latin America and Asia, the increase in population has been so rampant to the extent that treatment facilities were not able to deal with the issue of excessive sewage production. Over the years, the revolutionization in industries has resulted in the production of chemicals that have significantly damaged water quality. Most rivers and lakes record high levels of eutrophication due to the release of agricultural wastes in surface water. Groundwater is also affected due to the release of agricultural products in water. This is the case in various parts of the world. Air pollution due to industries and other sources has resulted in many water bodies having acidified water. Acidification of rivers and lakes poses a threat to natural ecosystems more so aquatic organisms as most of them cannot tolerate such pH levels.

For these reasons, air pollutants are considered a major source of air pollutants are considered a threat to water quality as most of these pollutants can easily dissolve in water forming certain chemicals and compounds. The ever-increasing population poses a threat to water quality as it increases the demand for various resources. This has resulted in the increase in mining and other human activities. This means that more industries will be opened to process these elements. There will also be a great demand for electricity among other resources. In the case of power generation, hydroelectric stations have been established along rivers and lakes to allow power production. These power plants usually establish storage containers therefore disrupting the normal water flow. In as much as power production is useful in helping human beings perform numerous activities, it poses a threat to water quality. Human activities have brought about climate change experienced in different areas. Climate change has brought about the fluctuation in the availability of water. It has also affected water quality both directly and indirectly. For instance, high rainfall is very useful in controlling the concentration of various elements in water (Figure 1.12).

As various human activities pose a threat to water quality, Integrated Water Resource Management was developed to try and deal with some of the threats. The main goals are to help regulate the extent to which water is exploited in various environments which will in turn help control and reverse the declining water quality in various countries. This is achieved by reaching a certain level of scientific understanding of how biological, chemical, and hydrological processes are interrelated and how they affect aquatic systems.

Figure 1.12. Numerous efforts have been put in place to help prevent selenium water contamination. Currently, there are various physical and chemical techniques that can be applied to remove the compound from water.

Source: http://www.wateryouthnetwork.org/integrated-water-resources-management-iwrm/.

This will be useful in developing, designing, and implementing Eco-hydrological solutions to issues of water quality. This will affect the manner in which water is used, treated, and extracted. The concept of solving environmental problems is referred to as eco-hydrology. Eco-hydrology revolves around the manipulation of hydrological and biotic interactions to bring about anthropogenic changes. It therefore explains and quantifies existing relationships between biotic dynamics and hydrological processes at a given scale. The process works on a few assumptions one being that the availability of sustainable water resources is dependent on the ability of one to maintain and restore evolutionary processes exhibited in water. For this to be successful, there in need for ne to possess knowledge on various cycles occurring in water.

There are various processes that occur naturally ad are affected by human activities. They all have different effects on water quality. They are discussed in subsections.

1.3.2.1. Sedimentation

Human activities involving land use are known to cause sedimentation. They include agriculture, mining, forestry, urbanization, industrial activities, and forestry. These activities cause the movement of sediments from one area to aquatic ecosystems. High rates of the movement of sediments are mostly

note in banksides more so in areas where farming is conducted along the banks. In most countries, planting of vegetation along riverbanks has been banned as many rivers have been destroyed due to siltation of soil from the farms. Another form in which sediments get to aquatic systems is through the construction of impoundments. Establishment of these impoundments results in sediments getting to rivers therefore modifying natural sedimentation exhibited in rivers by increasing the amount the sediments being deposited in rivers. These sediments then accumulate in ecosystems. Increase in the amount of sediments getting into rivers and lakes has both chemical and physical effects on water quality and the natural health of aquatic ecosystems. The dangerous effects of sediments in water are that it limits the amount of sunlight reaching under water thereby limiting algae and macrophytes production (Figure 1.13) (Singh et al., 2015).

Figure 1.13. Mining has contributed to the increase in selenium sedimentation in lakes and rivers.

Source: https://unsplash.com/s/photos/mining.

It also limits the amount of fish present in the ecosystems. This is because fine sediments usually make their way to the spawning gravel of fish making them unable to breathe properly. It also places a challenge on fish eggs as the fine sediments rest on their membranes and limit the amount of oxygen reaching the developing fish. These sediments also irritate fish when they rest on their skin. Some of the sediments find their way to fish gills and scour them. It also tampers with their visibility limiting their ability to get access to prey. The challenge with very fine sediments is the fact that they are chemically active. This is because they contain certain elements that are

chemically active. Among these elements is phosphorus and other metals. These elements are said to be highly attracted to ionic exchange sites more so those having components of selenium, magnesium, and iron. Siltation is usually linked to the presence of pesticides in water. Chemicals found in the pesticides contribute greatly to eutrophication processes witnessed in rivers.

The other challenge of heavy presence of sediments on water surfaces is that it increases chances of thermal pollution occurring resulting in higher water temperatures. In terms of water quality, presence of sediments in water lower water quality. In most cases, water heavily filled with sediments tend to carry pathogenic micro-organisms increasing chances of human beings and animals getting sick. Purification of such water involves the removal of both fine and course sediments which is very costly. (Sabuda et al., 2020).

1.3.2.2. Eutrophication

This is the process where by chemical components found in water are broken down by aquatic organisms resulting in an increased amount of nutrients in water. Human activities have largely contributed to the increased levels of eutrophication through activities like forestry, urbanization, agriculture, industrial effluents, and impoundments.

Figure 1.14. Intensive agriculture is essential in preventing selenium contamination in water systems.

Source: https://thumbor.forbes.com/thumbor/fit-in/1200x0/filters%3Aformat%28jpg%29/https%3A%2F%2Fspecials-images.forbesimg.com%2Fimageserve%2F5ea0bf898c2caa0006e718e2%2F0x0.jpg

Water sources majorly affected by eutrophication include ground water sources and surface water. Some of the rocks present near these water sources contain high levels of nutrients that find their way in to water. Another instance is when water rich in nutrients find its way to groundwater sources. In other cases, the high level of eutrophication in water is as a result of the excessive production of algae which breakdown chemical in water creating nutrients. The major challenge presented by eutrophication is the fact that it facilitates the fast growth of algae and other aquatic plants. This creates and intense competition for oxygen among other resources (Figure 1.14).

In most cases, presence of numerous aquatic plants and algae cause oxygen depletion in rivers resulting the death of aquatic organisms. Another problem is the fact that the availability of surplus amounts of certain nutrients create an environment favorable for the production of cyanobacteria. This bacterium is known to produce toxins that could be dangerous to human beings and animals. Eutrophication is also known to cause the disappearance of certain species of animals and it causes oxygen reduction. This in turn affects biodiversity in aquatic animals. Though some organisms are able to thrive in highly nutritious environments, there are those who cannot tolerate such conditions.

Some of the effects of eutrophication in human beings include water having bad odor as well as taste. Also, such water contains bacteria such as cyanobacterial which produce toxins that can cause illnesses and poor health in animals and human beings. High concentration of nitrates in water is a threat to human health as it causes various problems such as methemoglobinemia, reproduction problems and stomach cancer. Human activities have led to the significant increase in eutrophic levels. Over the years, there has been a global challenge of climate change brought about by the cutting of trees. Among the efforts made to curb the problems is planting of trees. In most areas, trees have been planted along riverbanks. As they grow, these trees introduce some nutrients in water. When cut, they decompose and produce certain chemicals and elements released in water. In the agriculture sector, improper application of fertilizers has resulted in some chemicals finding their way into water sources. If done frequently, these chemicals build up to exceedingly high amounts. In some ecosystems, aquatic organisms have been useful in reducing the amount of nutrients in water (Raymond and Ralston, 2020).

1.3.2.3. Thermal Pollution

Increase and decrease in water temperature has been caused by human activities such as agriculture, industrial effluents, urbanization, and impoundments. Industrial effluents are among the major cause of temperature changes in water temperature. For instance, in steam driven industries, selenium effluents leave the industry at a high temperature and is directed into rivers or lakes. Heat from the effluents is transferred from the effluents to the water body. This is witnessed in power generating plants. Temperature fluctuations is dangerous to aquatic organisms as they are able to tolerate a certain level of temperature.

1.4. EFFORTS MADE TO IMPROVE WATER QUALITY

As human activities have contributed to the decline in water quality, efforts to improve water quality mostly involve the regulation of human activities causing the degradation. There are relevant bodies placed in charge of water monitoring, regulation, and improvement. Among the efforts put in place to reduce the degradation in water quality include controlling farm contaminants. Agriculture causes eutrophication in rivers and lakes more so if chemicals were not properly sprayed in water. For this reason, there are regulations put in place to control the spraying of pesticides and acaricides in farms. In some countries, farmers have been banned from conducting any form of agricultural activities near water sources, rivers, and water catchment areas. In some countries, some pesticides have been prohibited for use as they are highly toxic and if they find their way into water sources the results could be catastrophic. As most of the elements in the pesticides are carcinogenic. Mitigation tools have been adopted in the agricultural sector to minimize case of eutrophication.

In relation to agriculture, sedimentation is a major issue as soil from the tillage process finds its way to river banks. The manner in which farmers conduct their farming practices affect the likelihood of sedimentation occurring. For instance, farmers conducting farming practices are advised to plant crops across the slope to avoid soil from becoming very loose and going down the slope increasing the amount of sediment reaching rivers and slopes. Most of the soil particles are carries by agents of soil erosion. These agents include wind and water flowing down stream. Also, soil erosion can also be reduced by planting trees on hills and near water sources and streams. Trees act as wind breakers reducing the strength of wind. This limits the amount of soil that can be displaced. Another advantage of planting trees is

that its roots hold soil particles together reducing chances of wind erosion. However, forestry should not be extensively done across river banks as it could result in trees taking up most of the water supply. This distorts the availability of water. It is advisable for certain species of trees to be planted near stream or rivers experiencing high levels of pollution. Bamboo is among plat species that help improve water quality. This species of trees is said to be a nature's natural filter. Bamboo takes up contaminated water. Impurities are absorbed as water flows through the plant. The plant retains the impurities and releases purified water (Papp et al., 2010).

Also, governments have put in place measures to minimize pollution. This includes regulations to control the amount of effluents released in rivers. In some countries, industries have been allocated areas where they can offload their wastes. In other countries, industries are required to conduct some water purification processes to ensure that effluent reaching rivers are not highly toxic. Among the major threats to ecosystems is release of effluents causing change in water temperature. Temperature changes are not good for aquatic animals as some organisms are sensitive to certain temperatures. For this reason, there are laws that require companies to ensure their effluents are cooled down before they are released in water. They are also required to filter out and components that could cause air pollution. This is to reduce the release of air pollutants which combine with water resulting in the formation of acidic water. Currently industries are required to be fitted with filters on their chimneys. These filter systems trap the pollutants are collected and released in waste land areas.

A major issue with water quality is availability. In most cases, water is not properly utilized by individuals in that it is used excessively. This includes water running at homes or power generating companies drawing large amounts of water and putting them in storage tanks. This should not be the case. In most developed countries, there are ministries in charge of water. The role of the Water Ministry is to control the amount of water being supplied to homes. They also limit the amount of water that can be drawn by industries for industrial purposes. In aquaculture systems, it is important for farmers to ensure that feeding is moderately done. This is to reduce the buildup of nutrients in water. This is useful in controlling the buildup of water hyacinth in water. For rivers having numerous numbers of water hyacinth, they should be removed to allow oxygen to be regenerated and light to pass through allowing the growth of plankton. This is useful in ensuring the survival of aquatic animals such as fish as they feed on plankton.

In conclusion, it may be quite difficult to create a definitive picture of water quality levels in a global scale. This is because environmental issues faced by a certain country may not be the same as the one faced by another country. However, as water quality is needed in ensuring good human health and the sustenance of ecosystems countries are required to make necessary efforts to ensure that water quality is maintained. This includes research being done on possible methods of improving water quality. Water stations can also be improved to allow researchers collect accurate data. Water purification station should be established and fitted with the best technologies. The environment should be taken care of so as to minimize chances of pollutants getting to fresh water sources.

CHAPTER 2

WATER QUALITY ASSESSMENT

CONTENTS

2.1. INTRODUCTION

On the earth's surface, water is present on the hydrosphere. It is normally described as the discontinuous shell on the earth that is found between the atmosphere and the solid earth crust. It includes the oceans. Seas and water found on the surface of the land. Ideally, subsurface water, snow, and ice also form part of the hydrosphere. The larger percentage of water is present in the oceans and seas, followed by the ground water and then the snow and ice present in the arctic and the Antarctic. Bio-related water, surface water and atmospheric water also form some percentage of water present in the hydrosphere. Of the fresh water that is present in the hydrosphere, 1% is the amount that is consumed, 69% used in agriculture, 23% is used in the industries and 8% is use in the domestic homes (Figure 2.1).

Figure 2.1. Farmer irrigating her farm using a pipe. Around 69% of water is normally used for agricultural purposes. Plants are very effective in reducing selenium levels in water.

Source: International Fund for Agricultural Development.

Water quality refers to the chemical, biological, and physical characteristics of water. The other general definition used in describing water quality is that of whether or not water has been polluted. It is however required to describe water quality as the condition the water is in compared to the requirement of one or more of the biotic species or to any human needs and purposes for using the water. The most common standard that is used to measure the quality of water depends on how the water affects the health of the ecosystem or health of the human beings. This also considered the use of water in drinking and how it affects the species that consumes the same.

As a matter of fact, individuals claim that understanding the subject of water quality is considered to be very complex given the fact that water is also a complex medium. This means that years and years of study with regard to the same will not exhaust all the mysteries that lies on understanding water. It is rather important to first understand the water qualities (Ojeda et al., 2020).

2.2. QUALITIES OF WATER

The quality of water shows the appropriateness of water in sustaining different uses. Various uses of water requires the water to have particular physical, chemical or biological characteristics. For example, water that is required for human as well as for other living things consumption is required to have minimal or no toxic selenium concentrations. There are additional limitations on the temperatures and the pH ranges of the water in the various uses. Thus, many studies have defined water quality according to the range of its features that could limit its uses in specific ways. The many various uses of water demand certain water qualities although most of the uses have common requirements in the water standards. However, the quantities and qualities needed for a particular use may not always be compactable while the activities of one use may limit the activities of water in another use due to the scarcity of water. Moreover, one use in its act ivies may demand qualities of water that are outside the qualities needed for watering another use or one activity may lower the qualities of water for it to be used in another activity (Figure 2.2).

Figure 2.2. Symbols to determine selenium water quality.

Source: APEC Water Systems.

Mankind have put in place various strategies in bids of maintaining or conserving as well as improving though the efforts compromise on either enhancing the water quality or its quantity for the different activities in need of usage. The natural ecosystems have however been reported to be having special functions in terms of maintaining and managing the water quality. As much as the natural ecosystems have internal values on water, qualities they provide information on the physical as well as chemical state of water. This is because they are sensitive to water quality deterioration and also changes. Water depends on natural factors such as geological, topographical, meteorological, and hydrological as well biological for composition (Lemaire et al., 2021). This is for both the surface water and the underground waters. In the drainage basin, it varies with the different seasonal factors such as the runoff volumes, weather conditions and water levels available. Water variations between different places or regions may be observed due to the large natural variations of the ecosystem in the specific places. This is also the case even when single water sources are involved.

Humans have from time immemorial had significant effects on the quality of water. This is as a result of mankind's activities such as building of dams, draining of wet lands and diversion flows that result to hydrological changes. Mainly, mankind is known to involve themselves with activities that lead to water pollution such as discharging the various wastes of domestic, industrial, urban into the water bodies. Application of chemicals into land for agricultural activities also causes contaminations of water bodies around the lands due to runoff of water. Therefore, the water quality is thus affected by a wide range of natural and human factors. For the natural factors the geological, hydrological, and climatic features influence the water quality as well as quantity available in each area. Their impacts on the water quality are greatest when there is limited or minimal water with many uses attached to the limited resource. For example, water has high salinity levels mostly the arid and coastal areas where water is scarce. Due to the limitations on the financials and technical requirements needed to desalinate sea and saline water in the underground of this areas the water remains saline. Therefore, the water available in these regions though in adequate quantities, may be unsuitable for uses purposes due to it quality.

Changes in the water quality disrupt the ecosystems functionalities. The ecosystem has been known to be disturbed by the various human activates to various degrees. Pollution attributed from the many human activities influences the water quality as well as the preventive measures available for preventive remedial activities in the ecosystem. Fecal pollution that

may occur among humans due to lack of community facilities for selenium disposal or they are inadequate or improperly operated systems in dealing with the collection as well as treatment or alternatively due to the onsite sanitation facilities such as latrines which drain to aquifers may affect the water quality as well as the ecosystem. The effects to the ecosystem may be such that it may causes intestinal diseases to humankind in most developing countries households. In the developing countries, the problems may be organic load and eutrophication where by sewage or effluent wastes are discharges into the nearby flowing rivers. This may as a result raise water quality limitations or challenges in various ways just as the challenge would have a number of influencing factors.

The process of eutrophication in the ecosystem results from points of sources of waste water discharge having high nutrient loads with especially high concentrations of nitrogen and phosphorous. Additionally, the challenge is also cause by various sources such as wastes to the water as result of runoff from livestock feedlots or the agricultural land, which may be applied fertilizer or organic or inorganic concentrations.

Figure 2.3. The highest quality of domestic water is one which does not contain any selenium impurities, this can be used for drinking or preparing food.

Source: Fontis Water.

The water pollution that may result from agricultural activities and other small inputs toxic substances over a wide area such as the fecal pollution

experienced in the unsewaged settlements are difficult to mitigate or control. Other authors have described the water quality as a term used in describing the concentrations of organic and inorganic materials available into the water coupled with the physical characteristics of water (Figure 2.3).

Water quality is determined by the *in-situ* features in measurements and scientific examination of different samples in an area from the laboratory. The various procedures involved in water monitoring activities are such as collection, analysis, study, and evaluation of the analytical results as well as reporting the findings generated form the study. The results are however on feasible for usage on the particular area from which the water is acquired and within the specific time period the samples of water were taken. The practices are very common among various stakeholders in the efforts of gathering sufficient data by the use of regularly intensive sampling analysis procedures. This is mainly in the efforts to access the spatial and temporal variations of water quality of a certain region. The nature of the aquatic environment is described by the composition and the state of the biological life available in the water body. In addition, it is determined by the nature of particulate matter and the physical nature of the water body such as hydrology and dimensions. In assessing the qualities of aquatic environments researches, need investigate and evaluate the water quality, biological life in the systems, particulate matter available and the physical attributes of the water body to come up with complete information of the state (Lenz and Lens, 2009).

The studies on aquatic environments could be carried out by analyzing the chemical analysis of water, particulate matter as well as sample analysis for the aquatic organisms such as the plank tonic algae of the available species in the waters. Tests such as biological tests for toxicity levels are also imperative. In addition, scientists may involve themselves in measuring the enzyme activities as well as describe the aquatic organism's features in their existence, density, biomass, and diversity from which they originated. This may be attained by developing a biotic index or microbiological patterns as well as the physical properties of water temperatures, pH levels, conductivity, light penetration attributes, particle size when suspended and the deposited materials into the water body, which affects the dimensions, flow velocity and the hydrological balances of water. According to GESAMP, pollution in the aquatic ecosystems is attributed to the human's activities that discharge their waste directly or indirectly. For example, this is done though atmospheric and the water management practices and uses. The resulting effects of contamination of the waters are such as hazards to the human

health, negative effects to other living things such as hindrances to aquatic activities such as fishing, harm in use of the water quality in uses such as for the agricultural activity, industrial, and other economic enterprise creating selenium as a by-product, as well as the impairment in the amenity values.

The importance on the quality of water is most of the time attached to the actual or planned uses. For example, safe drinking water should be free from chemical components that could be hazardous to humans. Due to the availability of wide ranges of water, qualities there are no universal standards to which the ranges are given for comparability purposes. However, unknown natural or pre-polluted qualities of water may establish references from surveys and studies of unpolluted waters in which they share natural conditions or the natural conditions are similar in the study.

Features in the surface's waters are such as the hydrological characteristics. This is from the various wide ranges of flowing water, lakes, reservoirs, and ground waters in the continental water bodies. The water bodies are interconnected by various hydrological cycles both in the natural and artificial circles. In the wet lands, areas for example in the floodplains, marshes, and alluvial aquifers the hydrological components are intermediate with those of the rivers, lakes, and ground waters.

Figure 2.4. Underground water example. The flow pattern shows the minimal requirements. Underground water systems like wells are at a great risk of selenium contamination from industrial discharge.

Source: National Geographic Society.

The wetlands and marshes are known to be having special biological functionalities in the ecosystem. Karstic aquifers may vary within time

rages of days as well as of years depending on the extent of the recharge in place. In fact, some karstic aquifers in the world have more than about 10,000 years of existence. It is very imperative that the hydrology data of the water body be included in the analysis of its quality. The minimum requirement that may be needed would be the seasonal variations in the river discharge, the thermal and mixing regimes of lakes, and the recharge regime and underground flow pattern of groundwater for analysis of quality of water purposes (Figure 2.4).

Residence time is another important feature in measuring the quality of water. This is acquired theoretically by taking the total lakes volume divided by the total outflow rate of the water. In the water pollution studies, the residence time is particularly important, as it is essential in determining the time taken in recovering a water body or aquatic ecosystem from a polluted state. In a river, for example residence time aids in the recovery of aquatic environment form an input pollution by rapid dispersion and with the transportation of waterborne pollutants out of the water sources. The rivers experience short residence time while long residence time are experienced in great or large water bodies systems such as deep lakes. The long residence time is associated with slow recoveries from the pollution inputs. The processes lead to transportation of the pollutants out of the water bodies within years or even decades depending on the size of the water body. the polluting agents that are located or stored in the sediments takes long time periods in being extracted from the ecosystem even when the water residence of the water body could be termed as short. The rivers flow id often unidirectional and contains good lateral and vertical mixing patterns which vary with the meteorological, climatic, and drainage conditions and patterns.

In the deep lakes or in the reservoirs the waters are still at the surface. These waters are characterized by alternating periods of stratification as well as vertical mixing from time to time. Further, the water currents are mostly multidirectional with much slower velocity as compared to rivers. The upper level of water is most of the time influenced by wind on its movement. In fact, most studies have estimated the residence time for the waters in the deep lakes to be taking more than six months to several hundreds of years. In the reservoirs however, their residence times may go up to one year. Stratification features are among other feature of water bodies that influences the quality of deep waters such as lakes and other natural reservoirs. The condition occurs when the water in the same water body behaves a manner to suggest that there are two or more different waters contained in the same

area. It may be observed that one may be floating on the other due to the differences in density of the different waters. This condition in most water bodies is attributed to difference in the temperature levels as a result of differences in the densities of water, which has a maximum density of 4°C. Other reasons for stratification in a water body would be due to difference as a result of solute concentration levels. The water quality in the water body in the two layers is however different and is subject to different influencing factors and influences.

In stratified waters the surface level of water receives, more sunlight while the lower level is typically separated from the access of oxygen and the atmosphere in general form the surface. The ground layer may be into contact with decomposing sediments and other toxic materials, which exerts any oxygen demand and thus in turn may lead to lower levels of water qualities. The decomposing matters and other toxic substances from the underground water may dissolve into the below level of water through the process of dissolutions or reduction (Lampis et al., 2014). This decomposed matter contains high levels of compounds such as ammonia, nitrate, phosphate, sulfide, silicate, iron, and manganese. Most studies for many years have engaged themselves in the study of temperate lakes thermal stratification in the temperate regions.

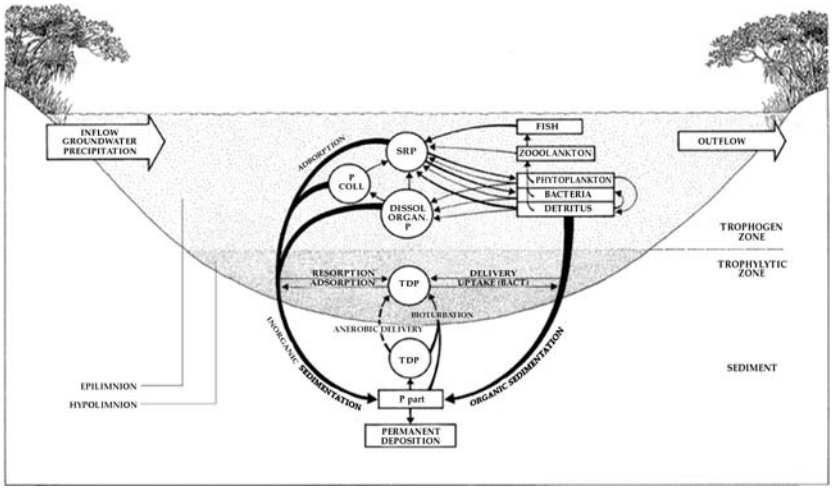

Figure 2.5. Selenium is the warm surface area. Selenium on the top of any water body is mixed by factors such as the wind and surface currents.

Source: ScienceDirect.com.

They found that during the spring and summer periods the surfaces of water in the water, bodies became warmer and their densities were lower. Consequently, the above layers would normally be colder and with higher densities as compared to the below waters. The warm surface layers are termed as epilimnion while the colder surface located underneath is known as the hypolimnion. The epilimnion which is on the top of any water body is mixed by factors such as the wind and surface currents resulting to temperature differences with the underground waters temperature ranges with the depth (Figure 2.5).

In between the stratified layers of water there exists a shallow zone known metalimnion or also termed thermocline layer. The layer converts the temperature changes between the different layer regions. This is such that as the weather in the atmosphere becomes cooler the and the difference in the densities between the layers is reduced the wind thus gets a space for inducing vertical circulations and water mixing thereby resulting to overturns with a very limited time period depending on the temperature, insulation, and the wind. Additionally, the feature in the wind as well as the surrounding wind exposure levels highly impact the time take for the overturn of temperature between the stratified two-level waters in the water body. The levels of overturn have led to the various types of lakes classifications. For example, the monomictic type of lake is believed to be turning once every year. This mostly occurs for temperate water bodies that do not freeze. On the other had there are dimictic lakes that overturn twice in a year which are characterized by the attribute of freezing. There exists the lake that overturns several times in a year, which is mainly shallow, temperate, and tropical lakes. These types of lakes are known as the polymictic. Amictic types of lakes do not mix. They contain arctic and high altitudes permanent ice coves that make it hard for the lakes to turn. Alternatively, there exist oligomictic and meromictic lakes that are characterized by poor mixing and incomplete mixing, respectively. However, this classification of lakes is not usually meant for the lakes that are less than 10 meters deep. This is because lakes that are shallow experience allot of wind which encourage mixing of the waters. (Kunhikrishnan et al., 2017).

Water bodies that are shallow in depth may be completely mixed severally times in a year while the deep lakes may persist stratification even including the tropical and equatorial areas. Permanent stratification in lakes is known as meromixis. In the water, bodies that are found in the tropical areas have the characteristics of having small temperature variations while the waters have high temperatures with low attitudes. In the case that the

altitudes start, increasing the temperatures of the waters falls consequently and proportionately. The discharge regime in water is another trait in water that may be used in the interpretation of water quality. This is especially for the waters including the suspended sediments or selenium contaminants. The level of discharge for example that of a river is mainly attributed to its catchment, particularly the geological, geographical as well as climatologically factors (Figure 2.6).

Figure 2.6. Suspended selenium sediments in a waterbody. This may be used in interpreting the quality of water.

Source: Fondriest Environmental.

The water quality of the ground water may be attributed to the composition of the recharge water, sol-gas, and rocks that comes into contact with it as well as the interactions that happen between the soils and water which are into contact with the unsaturated zones as well as the residence time taken coupled with the reaction activities that would take place within a water body. Consequently, variations are seen in the same areas specifically where the rocks of different matter compositions occur and solubility levels. Generally, the main features that used in classifying the water qualities is the physical which comprises of the ability of the water to dilute or disperse, filtrate, and allow for gaseous movements. More over the geochemical compositions that entails the waters completion, acid base reactions, oxidation-reduction, precipitation solution and adsorption desorption as well as biochemical factors are imperative in measuring the water quality.

Although water degradation in quality is mostly affected by human activities, there exist natural processes leading to falls in the quantities of water below the required levels for usage. Natural disasters such as torrential rainfall and hurricanes may lead to excessive erosion and landslides that causes increases in the contents of suspended contents in the water bodies. Moreover, seasonal overturns in the waters of some water bodies may lead to little or no of oxygen dissolved in the waters thus affecting the quality of water. In nature these events are expected to happen frequently. Some natural permanent conditions of some regions may lead to the waters available in those areas not to be fit carrying out the various uses. For example, the saline waters found in mostly the arid and coastal regions are unfit for drinking and irrigation purposes. Additionally, many ground waters are characterized by natural hardness due to high levels selenium thus require to be treated before use.

The quality of water is normally determined by assessing the three cases of parameters which include biological, chemical, and the physical aspects that make up the water. The biological parameter involves the biological attributes, which include the number and the types of organisms that are present in the water bodies. The chemical parameters include the DO, COD, BOD, Hardness, salinity, pH among other characteristics. Assessing the quality of water with regard to its chemical components involves measuring a number of elements, molecules that are either dissolved or suspended on the water surface. The physical parameters that are used in assessment of water includes the temperature, TSS, TDS, color odor among others. All these aspects that are being assessed are very important given the fact that they are of primary importance when considering the quality of drinking water. To be aware of the way to assess water quality, it is paramount to grasp the concept of water quality indicators and the criterion of water quality (Kaur et al., 2021).

2.3. WATER QUALITY INDICATORS

Water that is of good quality will help in maintaining biodiversity of both aquatic and terrestrial organisms, i.e., both animals and plants. It also guarantees the health and wellbeing of humans so as they can keep on with their day-to-day lives. The quality of surface and ground water is always and continually under pressure given that, there is some physical modification and the constant pollution from various sources. In order to address the water quality issue although hard there needs to be correct water quality monitoring

and reporting. It should be based on the indicators and indices. Indicators in this instance refers to single parameters that are used to measure the water quality, e.g., dissolved oxygen, phosphorus, Ph., temperature, turbidity, and others.

There are several indicators that are used and they include chemical, physical, and biological factors that are monitored. These indicators although being effective they also need to be efficient. When being measured the cost and effort needs to be reasonable and should not require any specialized skills. In water quality indicators, there is physio-chemical indicators and this is the most familiar with almost everyone. These include dissolved oxygen, ph., temperature, salinity, and nutrients, i.e., phosphorus, and nitrogen. In the same aspect, there are insecticides, herbicides, and metals, which are seen as toxicants but are chemical in nature. The physio-chemical indicators mostly identify the cause of the problem, as they are known to provide little information (He et al., 2018).

There are the biological indicators, which are the direct measures of the health of the animals and plants in a water ecosystem. The most common indicators that are used include benthic oxygen demand, fish diversity and benthic algal growth. In areas such as estuaries the biological indicators are less developed. The most common that is used is chlorophyll, which is used as a measure of phytoplankton population density. In the coastal areas, the indicators that are used include condition of the coral reef or seagrass condition (Figure 2.7).

Figure 2.7. Riparian water area, the type of water that flows and any floating debris determines the selenium water quality.

Source: Oregon Conservation Strategy.

There are habitat indicators, which is divided into two, i.e., riparian (fringing) and instream habitat. In the fringing habitat, it will depend on the species continuity, extent of shading, width, and its composition. On the other hand, instream will include presence of wood debris, scouring, and bank erosion, which are a habitat for some species. Then there is flow indicators. Changes to the natural flow of water which may have been caused by humans and they may include seasonality of the flow, base flows, peak flows, and no flow periods. For this to provide the best and accurate information there needs to be good flow data on the both the current and pre disturbance conditions. In most instances, this type of data is not available.

The major water indicators include; dissolved oxygen; the dissolved oxygen test measure the amount of oxygen that is found inside the water. As it is known oxygen is required by both plants and animals for various processes including respiration. When water has high levels of oxygen, the water can be harmful to both especially fish and other aquatic organisms. Nonpoint source pollution which can affect water decreases the amount of oxygen in water thereby reducing the oxygen and increasing other gases or elements in water which in turn will affect fish and other aquatic living organisms in the ecosystem. The decomposition of biodegradable organisms such as leaf litter, sewage, runoff from feedlots and grass clippings are some of the pollutants that decrease the amount of oxygen in water.

Figure 2.8. Biodegradable debris on top of water. They prevent entry of oxygen in water which helps to break down selenium into simpler compounds.

Source: USGS.

The amount of oxygen in water can be measured and it is measured in milligrams per liter (mg/l). The average and expected levels in fresh and clean water is between 4 to 11 mg/l. Water temperature is a very vital water quality indicator. Almost all organisms will depend on water that is of a

specific temperature range. A good example can be seen with the behavior of whale who have to travel over very long distances, i.e., thousands of miles to give birth, and they find food in some specific areas of the ocean (Figure 2.8).

Temperature will also affect other parameters inside the water, i.e., it will affect the amount of dissolved oxygen, the susceptibility of organisms to be affected by parasites, pollution or disease because some microorganisms will find too cold or too hot temperature to survive and they could even live there hibernating for hundreds if not thousands of years and the temperature can also affect the type of plants and animals present such as the mangrove plants that are only found on the shore of specific countries. The changes in water temperature can be caused by various factors and these are; shade, discharge from urban areas, i.e., most homes and industries release selenium pollutants into river sources. Temperature is measured in degrees Celsius (°C). The seasonal trend found in the United States shows that water temperature trends are; from May to October 23 to 36°C and November to April is 2 to 27°C (Hong et al., 2020).

Potential hydrogen, which is commonly referred to as ph., is the measure of alkalinity or acidity of water. A ph. of seven is considered neutral, below 7 is known to acidic and above 7 is considered to be basic or sometimes referred to as alkaline. Acid rain which is mostly caused by automobile exhaust and other pollutants cause a drop in ph. Accidental spills, agricultural runoff and sewer overflows are some of the factors that can change the ph. of water. Buffering capacity is the ability of water to resist changes in ph., and this quality is critical for the survival of flora and/or fauna that live in water. In central Texas, it has been known to have limestone soils which are sometimes known to neutralize the acid and with this, it means the water will be more basic in terms of ph. In most instances, young fish and insect larvae have been known to be able to tolerate and live-in water with low ph., but when it is in the extreme ends of the scale the organisms found I the water would be killed. The expected rand that most organisms live and survive is 6.5 and 9.0 (Figure 2.9).

Figure 2.9. Escherichia coli bacteria, which is present in water if contaminated by fecal material and selenium.

Source: Live Science.

The bacteria that arise from animal and human waste the *Escherichia coli* (*E. coli*). In most instances, the water that is used especially for recreation has to be measured whether it contains *E. coli*. The environmental protection in the United States measure it especially in areas where there are recreational parks that use water for entertainment purposes. Water that contains high levels of *E. coli* will most likely contain disease causing bacteria, protozoans, and viruses. When there are extreme rains and there is, flooding or water is directed into feedlots and animal feeding and sleeping areas there will definitely be increased levels of *E. coli*. It is measured by the number of colonies forming units. There is a required or recommended amount of colonies per every 100 m of water, i.e., 394 colonies.

The ability of water to conduct electricity or pass a current is referred to as specific conductance. Inorganic dissolved substances have been known to affect the conductivity of water and these solids include; sodium, calcium, sulfate, chloride, and other solids. In most instances the conductivity of a stream will be affected by the geology of the area in which the water flows. An example is a stream that runs through granite bedrock will tend to have low conductivity whereas the water that flows through limestone and clay will tend to have higher conductivity. Water that has been affected by industrial pollution or urban runoff, i.e., water flowing from streets, paring lots and buildings tends to have high conductivity. When there has been extended dry periods and there are also low flow conditions the water tends to have high conductivity. Water that has organic compounds example including oil will have low conductivity, as oi is known not conduct electricity well.

The temperature of water has also been known to affect the conductivity of water as warm water has high conductivity as compared to cold water. The conductance of water is measured in micro-Siemens per centimeter. The expected levels will range between 300 to 700 microsiemens and this is for water in the Colorado River, which looks to be higher than that of coasts and San Saba (Hasanuzzaman et al., 2020).

Nitrogen is a nutrient that is required by almost all organisms especially plants. It needed especially daring growth. The CRWN nitrogen tests are carried out to measure the amount of nitrate (NO_3-N). When there is excess nitrogen or nitrates in the water, it increases the amount of algae in water. The algae will then rob the water off the oxygen and this led to the death of fish and any aquatic life found in the habitat. There are various sources of nitrate pollution; lawns heavily fertilized agricultural land, industrial pollutants, and human waste among others. When the nitrates are too high, they can affect humans, i.e., 10 mg/l or more inside the water. When the water contains to high nitrate content, they have been known to cause serious illnesses and it has even killed infants. They are measured in milligrams per liter and the expected levels are 1.0 mg/l.

How far light can pass through water is the measure of transparency. As it is well known sunlight in nature is required for the process of photosynthesis to take place and tis will determine how far plants such as algae will grow and will all this it will show the ecological makeup of the water ecosystem. Water clarity will be noticed especially after heavy rains as silt, which has been carried, by water and selenium debris from runoff, which will cause reduction in visibility. In the United States especially during the summer, transparency will usually decrease because of plankton, silt, and organic matter, which are more prevalent during this season. The instruments that are used to measure transparency include Secchi disks and transparency tubes.

2.4. WATER QUALITY CRITERIA

These are the limits or thresholds the water pollutants and other water hazards in the natural water environment. The water quality criteria are provided for by scientists and they are to provide basic scientific information on the effects pollutants have on water on the specific water use. These criteria also provide the requirements for maintaining and protecting individual use of water. The criteria are based on valuables that characterize quality of suspended sediments, the bottom sediments and organisms that are found

in water. The criteria have set the maximum levels for particulates or substances in water when it is used continuously or used for a single specific purpose. There are some that the minimum levels are set, e.g., dissolved oxygen which can then ensure that biological function in the water is not interrupted.

The industrial processes do not provide demanding requirements on the quality of fresh water and the criteria is then developed for raw water used for drinking, agriculture, and recreation. The criteria can also be developed due to the aquatic ecosystems and the requirements of the organisms found in the habitat. For the protection and maintenance of the water uses different water requirements are set and they are usually different for each water use. There are sets of water variables that have been widely established and these variables include; biochemical oxygen demands for periods of between five to seven days, the chemical oxygen demand, dissolved oxygen, pH, and nutrients. Raw water that is used for drinking or that which is supplied for home use; the use criteria that are specific to inland water that is treated before being used at homes. In countries that are, developing large sections of the population depend on raw water for drinking without the water even being treated. The quality for raw water and drinking water criteria are generally the same especially water that is being directed to be used for drinking. The drinking water criteria will define the quality of water that will be consumed by human throughout their lifetime (Figure 2.10).

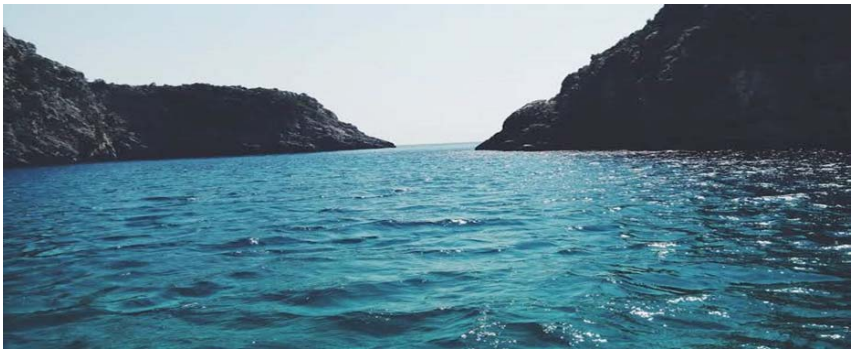

Figure 2.10. Raw water. Water that has yet to be treated of selenium is unsafe for human consumption.

Source: Science based Medicine.

The criteria have been developed by international organization such as the WHO guidelines for drinking water quality (GDWQ). In 2017,

based on more than 50 years of guidance, the World Health Organization (WHO) released the fourth edition of the GDWQ. It lays an authoritative foundation for the formulation of national water safety regulations and standards that support public health. The guidelines found in the criteria are used by member countries and are used for national drinking water quality standards. The water quality criteria for raw water that is used for drinking depend on the methods that are used for water treatment intended to reduce the concentration of contaminants to the level that is set for drinking water criteria. In the treatment of drinking water there is a range of how it can be treated, e.g., disinfection, and physical treatment, chemical treatment and disinfection and the intensive physical and chemical treatment. In many countries, they strive to ensure that the quality of water can only be supplied after using near natural conditions to ensure its safety for use (Cooper, 2021).

Water that is used for irrigation needs to be of good quality as water of poor quality can affect the crops that are being irrigated. This can cause accumulation of salt in the root zone because sodium and/or calcium do not leach because of loss of permeability of soil. When water contains contaminants, the contaminants will accumulate in the soil and after extended periods of time it will make the soil unfit for agricultural use. Even though the pathogens or pesticide presence can be acceptable for irrigation, water as it is acceptable but it will affect the acceptability of the agricultural produce in the market or will be unfit for human and animal consumption. There are several factors that are considered for water quality criteria for irrigation water and they include; selenium, sodium concentration, phytotoxic trace elements and crop tolerance to salinity. One of the most important factors is the effect of salinity on the osmotic pressure in the zone that soil is unsaturated, as this will influence the availability of water for plant use. When sodium is present, in water it affects the structure of soil and it will also reduce the rate at which water will move in and through soil. Sodium also directly affects fruits as it damages them before they mature. There are some phytotoxic elements such as heavy metals, boron, and even pesticides that will cause stunted growth in plants and will make the fruit unfit for human consumption (Figure 2.11).

Figure 2.11. Irrigation water needs to be of good quality, as it will affect the crop being planted or irrigated. The presence of selenium in agricultural water can reduce productivity.

Source: https://www.britannica.com/technology/irrigation.

Water that is used for livestock needs to have undergone quality criteria as livestock can be affected by water of poor quality. The water of poor quality can even cause death, some diseases and even impaired growth. The variables that are of major concern are total dissolved solids, metals, sulfates, nitrates, and organic micro pollutants that are found in pesticides. The blue-green algae which is mostly found in aquatic environments can cause major problems to livestock. Some substances can pass through the livestock and generally find its way to humans which means water quality criteria meant for livestock should be safe for human use too. The water quality criteria for livestock usually takes into account the type of livestock, the daily water requirement of the livestock species, the chemicals that are fed to the livestock to reduce risk of getting diseases and the toxicity of substances to the different animal species.

Water that is used for recreational use will be categorized based on the uses of the water in terms of swimming and any other sporting or leisure activity. The major concern for water quality for recreation is to ensure they protect the humans' health by preventing water polluted from fecal material or contamination from microorganisms that could cause ear, eye or skin infection or gastro-intestinal illnesses. The criteria are set for fecal pollution which include fecal coliforms and pathogens. Water used for recreational use is usually neglected or given less consideration. A good example is there are several areas in the coasts of South America that have been affected

by pollution such as the Guanabara Bay in Brazil, Cartagena in Columbia, and Vina Del Mar in Chile. These areas contain floating materials, there is offensive smell and many other pollutants like selenium will cause the area to be repelled on by tourists because of its low esthetic value, which reduces its visual appeal (Tanmoy et al., 2019).

There are some countries that have set criteria on the water for its esthetic value. This is also aimed at protecting the esthetic properties of water. All these are for the visual aspects of water the example of the criteria include that the water must be free from; floating debris, oil spills, excessive turbidity, other immiscible liquids, and bad odor. The criteria's that are used in this are non-quantifiable meaning this category only requires visual checking.

Commercial and sports fishing also takes water quality criteria into accounts especially accumulation of biological organisms and bio magnification in the higher trophic levels which can make the fish unfit for human consumption. The amount of a substance in the water has to be set to ensure the fish is fit for human consumption. In some countries, they have set the maximum amount of a substance that can be consumed by fish.

Figure 2.12. Sport fishing, fresh water in essential for fish to thrive and promote these kinds of activities. Fish cannot flourish is selenium contaminated water.

Source: www.frenzyfishing.com.

Some countries have set quality criteria for suspended particulate matter and sediments, which aim at achieving better water quality. For example, sediments that is dredged from a water body can be used for the improvement of soil that is used for farming. These criteria are set so as to protect organisms living in the water. When there is constant pollution and

constant pollutants have been shown to accumulate and magnified in the aquatic food chain leading to unacceptable (Figure 2.12).

Concentrations in the fish that live in the area and birds that consume fish in the area. There have been a few criteria that have been set because they have not reached an advanced stage.

There have also been set criteria for protection of aquatic life. With constant introduction of chemicals in water, they have been known to affect the aquatic plants and animals, which are dependent on abiotic and biotic conditions. This will only take into account the physicochemical parameters, which in turn defines the quality of water, protects, and maintains aquatic life.

The standards that are drawn by the EPA are considered to be the primary drinking water standards and secondary drinking water standards. The standards of water that are considered to be primary tend to regulate the organic and inorganic chemicals, radioactive elements and microbial pathogens that affect the safety of drinking water. The secondary water standards are considered to be in charge of regulating the color, coper, selenium, chloride, foaming agents, corrosivity, iron, pH, total dissolved solids, manganese, odor, sulfates, and zinc which may inevitably affect the quality of drinking water which include the taste of the water, the odor, the color, and the appearance. When drinking water, individuals expect that the water will have no odor, clear in terms of the color, have no metallic taste. Such qualities in water have proven to be hard to come by especially in the current society, which seems like pollution and industrial revolution is a daily norm (Okonji et al., 2020).

2.5. BIOLOGICAL ASSESSMENT OF WATER QUALITY

This involves the number and number of organisms that are present of the water body. Bio assessment of the macro invertebrates is one of the procedures that is normally used due to the fact that it is an inexpensive method and has been proven to be scientifically valid if one used the same correctly. This method provides a benchmark of other waters that can be compared and in addition to that can be used in describing the rehabilitation goals and also to monitor trends of the water quality. The quality of water in the ecology is related to the biological community and the conditions that these species live in. anthropological activities are known to affect or rather damage the

biological elements. In exchange to this, the biological communities act by modifying themselves in order to adopt to the new conditions and structures. This shows how dynamic and complex the biological ecosystem is. The aquatic macroinvertebrates are one biological element considered to be the ecological radar that can be used in the assessment of water quality. These macroinvertebrates are known to be very crucial components in the lake ecosystem. The role of this species is known to play a crucial role as related to the lake ecosystem with regard to the structure and functions that it plays on the ecological status of the lake (Figure 2.13).

Figure 2.13. Macroinvertebrates that are found in the water bodies. They play a crucial role in terms of structure and functions in the ecosystem. Selenium concentration in water can led to decline in the population of these creatures, potentially destroying the aquatic ecosystem.

Source: KBIC NRD website-Keweenawan Bay Indian Community.

In various studies, biological assessment of water quality involves the evaluation of water conditions by looking at the species that normally spend most parts of their lives in the waterbody. Easily said, it is a biological survey that is conducted to collect a representative sample of the biological community that is present in the waterbody. They can be described as the biological indicators that are normally used to compare with reference sites in order to allow one to understand the quality of water. The biological survey that is conducted is defined as the systematic method used in the collection the aquatic biological community from the waterbody in a consistent, reproducible, and reliable manner. The biological indicators are used to describe the organisms that are used to assess the condition of water environment (Garousi et al., 2016).

In most cases, the biological component that is used in biological surveys depend on the waterbody that is used in the sampling process. Some of the biological indicators that are normally used include fish, which may be trout, sunfish, perch, and salmon. There have been many cases of water pollution in the world even though most of the individuals are trying to come up with ways to reduce the toxic levels. In order to be able to reduce oxidation to the water body, it is important for individuals to first understand the levels of toxicity present in the water body. Measuring the levels of toxicity on the water can sometimes be misleading and thus the use of fish. In this case, the scientists will fish for some varieties and test them for the levels of toxicity present in them. This is more appropriate given the fact that fish is mostly consumed by most of the individuals around the world.

Figure 2.14. Amphibians can be very helpful in assessing selenium contamination of water. They are proving to be an endangered species and experts are working hard to protect them in the harsh environment. This should begin by preventing poaching.

Source: Biology Questions.

Periphyton is another biological indicator that is used in the assessment of the water quality. This includes the algae that grows in the water bodies. In most circumstances, an increase in the number of algae that is present in the waterbody clearly shows poor quality of water. Even though these plants act as fish food, an excess of the same may be dangerous to the water organisms. It may affect the oxygen levels that are present in the water and hence affect the quality of fish that is present in the water body. Amphibians are other

organisms that can be used as an indicator in assessing the quality of the water body. These normally includes the frogs and the salamanders. This is because these organisms are considered to be very sensitive to the changes in temperature and any other change that may take place in the environment. As such, they can be able to provide the scientists with relevant information on how the ecosystem is functioning. Amphibians are both predators and prey and thus can affect a great deal of animals. The species of amphibians come in large and small sizes. It is sad that majority of the species that fall under this category are endangered. As such, there are those experts of the same that are working day and night to try to save this species of animals (Figure 2.14).

Birds are also other indicators. One may even say that this is impossible given the fact that most birds that access the water bodies tend to be migratory birds. There are however those that are residential and live in a particular waterbody for a long period of time. They however play an important role in understanding he water quality in the place they are present. It is thus necessary to acquire a sample of the birds just before they migrate in order to get clear results on the water body that they were residing at in that particular time. All these stated organisms play an important role in trying to understand the quality of water. Through them, experts can be able to know what needs to be done in order to reduce the selenium pollution levels in the water bodies. In the long run, they can be able to save individuals from injecting polluted water.

2.6. CHEMICAL ASSESSMENT OF WATER

The commonly measured water parameters that are used in assessing the water the quality include, pH, hardness, alkalinity, ammonia, phosphates, nitrates, ortho, and the dissolved and biochemical oxygen demanded. These chemical measures are also considered to be very important in determining the imbalances that are within the environment. In addition to his, the chemical components help in indicating the physical presence of pollutants in the waterbody. Such measures include the measures of conductivity and density. About the pH of water, one looks at the acidity and the basic levels of water. The range normally goes from 0 to 14 in which 7 is considered to be the neutral level. Ideally, pH is considered to be a measure of the relative amount of hydrogen and hydroxyl ions that are resent in the water body (Frankenberger et al., 2004). When water has more free hydrogen ions then it is considered to be acidic while the water that has more hydroxyl ions is

considered as basic. It is with no doubt that pH ca be easily affected by the chemicals that are present in water and can easily change with regards to the amount of chemicals that are resent. This is a very important indicator as one can be able to know whether the water is changing chemically and thus being able to understand the level of toxicity in the water body. This indicator is important in determining the solubility of water, biological availability and the chemical constituents present in the waterbody. With the pH, one can be able to know whether the water is good for drinking.

Hardness is another indicator that is very useful in assessing then quality of water. Simply put, hardness is the amount of dissolved calcium and magnesium in the water. Water is considered to be hard when it is high in dissolved minerals. This means that it is high in calcium and magnesium. Most people have had the effects of hardness of water especially when they wash their hands. Depending on the hardness of water, once one uses soap in washing their hands and felt some form of film then it means that the water that has been used is hard. Even at times when washing clothes. Hard water has a tendency of not forming any kind of foam. This is because in hard water, soap reacts with calcium to form soap scum and thus needs more detergent than the normal water.

When water that is used for home consumption is hard, then it is not safe for the human body. This is an issue of concern given the fact that when hard water is heated, there is formation solid deposits of carbonate, which is harmful to the human body. Apart from affecting the health of individuals, such deposits can reduce the life of an equipment, lowers the efficiency of the electric water heater, raise the costs of heating water, and clogs the pipes. Water pipes can be used to measure the level of hardness of water. Long-term movement of hard water in the pipes can lead to the buildup of what is known as scale just like how blood vessels reduce in size due to cholesterol build up. In the long run, the water pipes can close up which will result in less water moving through the pipes and further lowering the water pressure.

Alkalinity is another indicator used in assessing the quality of water. It should be understood that alkalinity is not a chemical in water but rather a property of water that shows the presence of certain minerals in water such as carbonates, bicarbonates, and hydroxides. Clearly put, alkalinity defines the capacity of water to neutralize the bases and acids present in order to maintain the pH of the water. This explains the fact that when water is high in terms of alkalinity, then it will not be affected by the acids or bases that will be introduced to the water body such as the acid rain. It means that the

water has a high buffering capacity. Meaning that the water can be able to protect itself from the new conditions that may negatively influence the water body. This is an important aspect to the health of the lake. In the current society, water is normally seen to be subjected to new chemicals and such a waterbody with high alkalinity levels can protect itself from some percentage of alkalinity. One method that is commonly used in measuring the alkalinity of water is by taking a sample of water and adding acid to the same. As the acid is added, one checks the pH of the water. The pH will remain constant up to some pond where the water neutralizing agents will be used up and in that moment the pH of the water will start to reduce. Water that is more alkaline is of higher quality compared to the one with less alkalinity given the fact that the water can be able to buffer itself from selenium chemicals (Feng et al., 2021).

Ammonia is the other chemical that is important in chemically assessing the quality of water. Ammonia normally considered to be non-toxic to the human life but is toxic to the aquatic environment. Once in water, ammonia breaks down to form ammonium ions and hydroxide ions. On itself, ammonia is harmful to the aquatic life but the ammonium ions are not. Ideally, once in water, there normally exists some form of equilibrium between these two forms of ammonium. In such state, the molecules are normally seen to change back and forth between the two states, which normally depend on the pH of water. Ammonium is known to increase the nutrient levels in the water body and in the process promote the growth of algae, which is not so good for the aquatic ecosystem especially when in extreme levels. When ammonia is present in the water body, the aquatic ecosystem absorbs the ammonium into their body and incorporates them to the molecules in their structures. Once inside their systems, it becomes quite difficult to excrete the same from their systems. In drinking water, ammonium can sometimes create an unpleasant smell and taste due to the formation of chloramines. Chloramines are normally formed when both ammonia and chlorine is added to the drinking water in order to disinfect it. Because of the fact that ammonia s considered not to be harmful to the human body, no standards have yet been set on the limit of ammonia that needs to be present in the water consumed by individuals. Poor taste and odor in water can indicate the presence of ammonia in water. In the case where water has a low level of chlorine, then it means that the water is high on ammonium. Levels of ammonium can also be measured in terms of pH. When the pH is low, it indicates high levels of ammonium in water. High levels of bacterial growth are also an indicator of higher levels of ammonium.

Phosphate is another indicator in assessing the water quality. In higher quantities just like ammonium, phosphates tend to increase the amounts of algae that grown in the waterbody. In most cases, phosphates are normally washed into water bodies and are known to pass through rocks. Those that are from rocks are non-renewable and thus need to be recycled in order to prevent the depletion of the resource from the earth surface. Phosphates are known to be harmless to human body, especially the natural ones. Although, those that have been modified by human beings have proven to be very dangerous. It is therefore very important to do a measurement of phosphates in water in order to ensure the health of human beings. Phosphorous and nitrogen are both considered to be very important nutrients for plants and animals that make up the aquatic life. Phosphorous is in low supply in the water bodies but individuals need to be careful when dealing with the same. When increasing the amounts of phosphorous in the water body, the amounts need to be minimal given the fact that if one does not increase the same in the right conditions, then it can bring about chain of undesirable events which include accelerated plant growth rates.

To monitor the phosphates levels can be very tricky given the fact that it involves measuring very low concentrations. This is because even very low levels of phosphates can have drastic effects in the water body. There are many tests that can be used in measuring the amounts of phosphorous levels but there are only four famous ones that are considered to be cheaper and efficient. There is the total orthophosphate test that is known to largely measure the orthophosphates that are present in the water. Since majority of the sampled water is not filtered, this procedure measures both the dissolved and the suspended ones (El-Ramady et al., 2020). The total phosphorous test is another one, which measures all forms of phosphorous including orthophosphates. It is achieved by heating and acidifying the sample of water collected in order to convert all the other forms of phosphorous to orthophosphate. It is then measured by the ascorbic acid method. The dissolved phosphorous test is another way, which is used in measuring the amount of phosphorous that is present and soluble in the water sample. As such, it is required that one first filters the water sample before deciding on measuring. To get the amount of insoluble phosphorous, one subtracts the amounts of dissolved phosphorous from the total phosphorous (Figure 2.15).

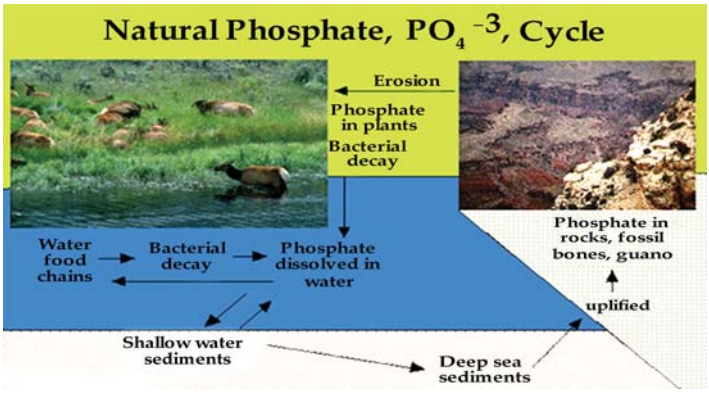

Figure 2.15. Natural compounds like phosphate and selenium are not harmful to the aquatic organisms but once manmade sources are introduced, it can have a high impact.

Source: Water-Research.net.

Oxygen saturation or dissolved oxygen is one measure in determining the amounts of oxygen present in the water body. It is normally carried out in a certain medium. It can be measured by the use of a dissolved oxygen probe, which includes an oxygen sensor or an opted liquid medium, which is usually water. This is normally termed as 'oxy-saturation.' The probes are normally like fuel cells or a semi-permeable membrane that help in showing the amounts of oxygen available in the water. Biochemical oxygen demand is another way of assessing water quality. It is defined as the amount of dissolved oxygen that is needed by the aerobic biological organisms that are present in the water body. This is measured with regard to the temperature of the water that has been sampled within a particular period. It is however not considered as precise quantitative test but, in most instances, it is used in indicating the organic quality of water. The value of this measurement is normally expressed in terms of milligrams of oxygen consumed per liter of sample that is collected. Water should be such that the dissolved oxygen can be replaced or rather added. In some instances, there are those individuals who do homemade aquaculture and tend to use machines to pump dissolved oxygen to the ponds in order to make the ponds a safe place for the aquatic environment. Chemical oxygen demand is another aspect that is used in assessing the quality of water in the water bodies. This is used precisely to measure the amounts of organic compounds that are present in water. Most applications of chemical oxygen demand are used in determining the amounts

of organic pollutants that are found in the surface water including the lakes and rivers or wastewater. It is normally expressed in terms of milligrams per liter. In acidic conditions, strong oxidizing agents are normally used.

2.7. IMPORTANCE OF WATER QUALITY ASSESSMENT

Every organism that is found in the surface of the earth needs water in order to survive. As a matter of fact, it has been discovered that a human being can last more than seven days with water and without food. In addition to this, food needs water in order to grow or even be cooked. Ideally, the human body is highly made up of water, which includes 60%. Clean water is normally used for the purpose of drinking, to grow crops that are used to feed both human beings and animals, operate the factories and for recreational activities such as swimming, surfing sailing and fishing. Although, fishing can be a commercial activity or a recreational activity depending on what exactly drives the person performing the activity. This shows how much water is considered as an important aspect in the life of each and every organism in the world. In the process of monitoring the quality of water present in the ecosystem can help in protecting the water bodies from pollution. It is only when one understands the water and its quality is when they understand how it is required to be in order to be harmless to the human body. (Banuelos et al., 2002).

Pollution has been a drastic component that has highly influenced the environment negatively. As a matter of fact, it has riven scientists to try to come up or invent ways that can be able to save the water bodies in order to prevent the high mortality rates that can be brought about by water solution. It has proven to be quite a challenge given the fact that majority of individuals do not appreciate the need to protect the water resource which is important in their lives. Providing education and researching on water quality and how to test for the same can be a step forward in trying to set the world to a direction in which can be beneficial to the human beings. Monitoring information is one of the ways in which the governments, farmers, and industrialists use in controlling the levels of selenium pollution. It proves to be quite difficult to measure the quality of water. This is given the fact that water is a vast network consisting of oceans, rivers springs, creeks, wetlands, lakes among others. As such, it is advice to each and every person to monitor the water that they use or release as waste and in the process, individuals can be able to recognize and prevent majority of contamination problems.

CHAPTER 3

WATER FOR ECOSYSTEM AND HUMAN HEALTH

CONTENTS

3.1. INTRODUCTION

The earth's surface is majorly covered by water and the human body is also majorly water. These are the two facts that show the critical linkages that exists between human health and the ecosystem. With the rise in the human population over the last decades, there has been an increase in the amount of water that is required. Yet the threat that still remains to most of the poor lives is the lack or insufficient water. In most instances, water available to the poor is mostly unsanitary and unfit for consumption for individuals. As a matter of fact, selenium pollution has proven to be a major challenge facing the water ecosystem and is affecting the health of the people. Consequently, millions of individuals have succumbed to this threat (Figure 3.1).

Figure 3.1. Water pollution. Pollution has proven to be a great challenge in the world and apparently, millions of individuals have succumbed from the same.

Source: History.com.

Apart from pollution, there are also other water related situations that have brought about death to the global society. Some of the situations include poor access to sufficient amounts of water and having contact with contaminated water sources. Nearly a third of individuals in the globe live in countries that have moderate or high levels of water stresses. Such as led to the situations of water rationing and selling of water, something that should have been free given the fact that it covers a large percentage of the earth. Scientists claim that, by the year 2025, two out of three persons will be living under water stress conditions. Population is still growing and the demand for water is rising and thus the world is facing a great threat especially if the world does not work together to reduce cases of pollution. (Déon et al.,

2017). There have been cases of elimination of marshes and wetlands and have been seen to have significant impacts on the freshwater ecosystem. Other aspects that have brought about changes in the ecosystem include the diversion of surface water and the alteration of the flow of water, exploitation of the underground aquifers and the contamination of water by human and industrial waste. Human beings have been known to be the greatest threat that faces the environment and the water ecosystem. Overconsumption is one aspect that has proven a threat to water. Overconsumption is a situation in which the use of a resource has been able to outpace the sustainable capacity of the ecosystem. This is normally measured I terms of the ecological footprint which is a resource accounting approach which compares the demand that individuals have on the ecosystem and what is actually present in the ecosystem and the amounts that can be renewed by the same (Figure 3.2).

Figure 3.2. Overconsumption of a water resource. Overconsumption of water has led to the reduction in the resource and may prove to be a threat as the population grows.

Source: Tehran Times.

Researchers claim that the current demand of humans on the earth's resources is 70% higher than the regeneration rate. With a prolonged aspect of overconsumption, there will be increased cases of degradation, which would eventually lead to losses in the resource base. Humanity's ordinary effect on this planet is tormented by many factors, now no longer simply the uncooked variety of people. Their lifestyle which includes ordinary affluence and aid utilization and the pollutants they generate (which include carbon footprint) are similarly important. In 2008, The New York Times said

that the population of the evolved international locations of the arena eat assets like oil and metals at a price nearly 32 instances extra than the ones of the growing world, who make up the bulk of the human population.

Water is one resource that is affected by human beings through pollution and overconsumption. An important resource is used for drinking among other developmental purposes. Safe drinking water is more important for the health of individuals all around the world. Water is known to be a universal solvent and thus a major source of infection. According to the WHO, 80% of the diseases are caused by water. Most countries around the world use drinking water that do not meet the standards of the World Health Organization (WHO) and as such deaths occur due to unhygienic and the poor quality of water (Domokos-Szabolcsy et al., 2018).

Discharge of home and commercial effluent wastes, leakage from water tanks, marine dumping, radioactive waste, and atmospheric deposition are predominant reasons of water pollution. Heavy metals that disposed of and commercial waste can collect in lakes and river, proving dangerous to people and animals. Selenium toxins in commercial waste are the predominant motive of immune suppression, reproductive failure, and acute poisoning. Infectious sicknesses, like cholera, typhoid fever and different sicknesses gastroenteritis, diarrhea, vomiting, pores, and skin and kidney trouble are spreading thru polluted water. Human fitness is stricken by the direct harm of plants and animal nutrition. These water pollutants have been known kill a number of aquatic species if not all of them that may or may not serve as food for consumption for humans (Figure 3.3).

Figure 3.3. The aquatic species are at a risk unless individuals across the world learn how to deal with pollution.

Source: Salon.com.

The rising population is seen to be creating many issues regarding the health condition of water as it highly contributes to pollution. This is because it brings about increase in the amounts of solid wastes and liquid waste that is discharged to the rivers. There is a great association between pollution and the health individuals. The disease-causing microorganisms known as pathogens are known to be the major reason for spreading disease among the human beings. Most of this water borne diseases are known to be spreading from person to person.

Figure 3.4. Poor members of the society are at a risk of infectious diseases given the fact that they do not have access to clean and sanitary water.

Source: Nonprofit Chronicles.

Cases of heavy rainfalls and flooding are extreme weather conditions, which tend to spread diseases for both developing and he developed countries. A small percentage of individuals depend on the food and vegetables that are grown on contaminated water. Some of the diseases that are linked to the cases of water pollution include neurological disorder, diarrheal diseases, cardiovascular diseases (CVDs), and cancer. Cancer and blue baby syndrome are some of the diseases that are brought about by nitrogenous chemicals. In the rural areas, majority of the individuals are poor and are the ones known to majorly succumb to cases of cancer unlike individuals in the urban centers. Due to the cases of classes in the economy, the rich are able to buy their way to acquire clean water while the poor have to live on poor conditions of rivers and lakes. As such, there are high cases

of mortality rates in the rural areas. Water bought by the individuals in the urban centers is normally treated while the poor do not have access to the facility of treated water and thus depend on unprocessed water. This is the reason as to why poor people are at a greater risk of being infected with diseases because of improper sanitation, insufficient water supply and poor hygiene (Figure 3.4).

Women who are pregnant are normally at a higher risk especially given the fact that they are exposed to chemicals which then leads to increased low birth rates and when children are born, they have reduced birth weights. Taking a case of China where cases of pollution is quite high, children are born with low weights and grow up to be small-bodied. Apart from affecting the human population, poor quality of water destroys the crop production. As such, it affects the food that we consume and those consumed by the aquatic life and it is hazardous. Such pollutants are known to affect the food chain and heavy metals especially iron which is known to affect the respiratory system of the fishes. The iron tends to clog the fish gills and becomes lethal to the fishes ad once human beings consume the fish, they tend to have a great health issue. Water that is contaminated by selenium normally brings about hair loss a neural disorder, renal failure, liver cirrhosis. Untreated water for drinking and fecal infection of water is the fundamental reason for diarrhea. *Campylobacter jejuni* unfold diarrhea 4% to 15% worldwide. Fever, belly pain, nausea, headache are fundamental signs and symptoms of diarrhea. Good hygienic practices and use of antibiotics can save you this ailment. Disease cholera is because of the tainted water. Vibrio Cholerae is accountable for this ailment. This bacterium produces pollution in digestive tracts. The signs and symptoms of this ailment are watery diarrhea, nausea, vomiting, and watery diarrhea results in dehydration and renal failure. Anti-microbial remedy is used to dispose of this ailment (Bini, 2009).

Shigellosis is another bacterial disease that is caused by shigella bacteria. It is known to affect the digestive tract of human and damages the intestinal linings. Some of the symptoms that are normally seen include abdominal cramps, vomiting, bloody diarrhea and nausea and they can be easily treated by use of antibiotics and good hygienic practices. Salmonellosis is known to infest the intestinal tracts ad is normally brought about by salmonella bacteria, which is found in contaminated water. It normally leads to inflammation of the intestines and in most cases; death is seen to overcome individuals affected by the same. For this disease, antibiotics are normally prescribed. Viral diseases are also brought about by water contamination. Hepatitis is one of them, which infects the river and is brought about by

contaminated water. Some of the symptoms of this disease include loss of appetite, jaundice, discomfort, and fatigue. When this disease persists for a long time, then it becomes fatal to the human body. Vaccine is always a good way to deal with hepatitis and it is always advisable to maintain a hygienic environment. Encephalitis is an inflammatory disease that is normally spread by a bite of an infected mosquito. Culex mosquito ate known to lay their eggs in contaminated water which is mostly their breeding step Most of the individuals do not normally show symptoms but in case it is seen, some of the symptoms include headache, high fever convulsion and muscle stiffness. In the case, where it is severe it may lead to coma and paralysis. There is no existing vaccine for this disease (Figure 3.5).

Figure 3.5. Some of the diseases brought about by contaminated water do not show symptoms but there are those that do.

Source: MDLinx.

Poliomyelitis virus is chargeable for poliomyelitis. Sore throat, fever, nausea, constipation, and diarrhea and from time-to-time paralysis are signs and symptoms of poliomyelitis. Vaccine is to be taken for this disease. Gastroenteritis is as a result of special viruses such as rotaviruses, adenoviruses, caliciviruses, and Norwalk virus. Symptoms of gastroenteritis are vomiting, headache, and fever. Symptoms seem 1 to two days after infecting. Sickness may be risky amongst infants, younger kids, and disabled person.

Water contamination can also bring about parasitic diseases. One is cryptosporidiosis, which is a parasitic disease that is caused by

cryptosporidium partum. This is a very common disease worldwide and some of the symptoms include loose or watery bowels, stomach cramps, diarrhea, and upset stomach. It is considered to be resistant to disinfection and is known to affect the immune system and causes diarrhea and vomiting in human beings. *Entamoeba hystolytica* is a bacterium that causes the galloping amoeba, which is known to affect the stomach lining. The parasite is known to undergo both the cyst and the non-cyst form and infection normally occurs when the cyst is found in contaminated water. Some of the symptoms include fever, chills, and watery diarrhea. According to the WHO, diarrheal cases around the world are close to 5 billion and cases of deaths are close to 3 million. Another case is Giardiasis, which is as a result of Giardia labia. Cells of intestinal lining might also additionally turn out to be injure. Giardia is proof against wintry temperature and disinfectant. Sometimes it is far referred to as travelers' disease. People stricken by giardiasis have signs and symptoms bloating, extra gas, watery diarrhea, and weight loss. Individuals need to be very weary of this disease as it can be the cause of their deaths.

As seen by the examples of the diseases that are brought about by water contamination, it is wise for individuals to be hygienic and take vaccines for the diseases in which vaccines exists. More important, individuals need to understand the importance of preventing water pollution in order to protect themselves from case of such diseases. This is due to the fact that there are those that can be spread from one person to another. This is given the fact that pollution has proven to be a global issue and, in the process, the world is facing the worst results from such cases of polluted water. Some of the major sources of water pollutants are discharge of domestic and agricultural waste, excessive use of pesticides, high population growth urbanization and fertilizer use. Diseases that are brought about by bacteria, parasites, and viruses are known to spread through contaminated water and highly affect the human health. It is thus recommended that human beings build better disposal mechanisms and before getting to the river, polluted water needs to be treated properly. In addition to this, it should be noted that the method used for treating the water needs to be natural enough so as not to make the situation eve worse for other environmental resources. To enable this, educational awareness should be provided so as to organize individuals in the fight for controlling pollution (Badr et al., 2020).

The reason behind wanting to preserve water quality is because of the fact that it is needed by the ecosystem to perform certain objectives. Such functions played by water include providing enough water for the ecosystem

to drink, for recreational activities and as a habitat for aquatic ecosystem. Without water, it could be easier to say that no life would be existing in the human planet. Taking for instance there are planets where there is no water, there is no any form of life and human beings who have wanted to make such planets homes have found them quite difficult to inhabit. Below are some of the reasons why water is needed for the environment and human health.

3.2. NEED FOR WATER IN THE ENVIRONMENT AND THE ECOSYSTEM

Water is very vital in every aspect of how living organisms conduct their day-to-day activities. The ecosystems on the planet are all linked and maintained to an extent by water. Water carries various roles and functions in order to propel plant growth, it provides dwelling for species that live inside it. It has been known that water provides a semi-permanent dwelling for some species; it also provides a breeding ground for some species most especially amphibians and some insects. Water has often been referred to as nature's most important commodity as there is the phrase "water is life" and many people see it to be true.

Figure 3.6. The Grand Canyon in the United States has been shaped by water over the years and its now one of the natural wonders on earth.

Source: Grand Canyon.

The important functions that need water include the transport of oxygen, nutrients, waste, and minerals to the cell and from the cells. In the digestive system of living organisms such as animals, water is needed to allow their

systems to function properly. It also lubricates the respiratory layer as it is found in mucous. For metabolic functions to be carried out water has to be present as well as in the chemical reactions in the body water plays a vital part (Figure 3.6).

Water is also very important as it helps in shaping the earth's surface. Several processes such as erosion, sediment transport, and water can form features such as valleys, deltas, flood plains and the beaches. There are also some subsurface features such as caves that ae formed by water. There some world wonders such as the Grand Canyon in the United States that is believed to have been formed by water. The sands that are found in the beaches are also believed to have been transported from the upland areas as water was moving down towards the ocean. Water is a very important commodity and even as a renewable resource it is not always available where or when it is needed and even when found it can be of unwanted quality. There can be too much water at a given time, i.e., floods or too little water, i.e., drought, and this may have serious consequences to the people, animals, plants, or microorganisms found in that area.

Figure 3.7. Rivers provide areas where people can relax, unwind, and connect with the environment.

Source: Discover GRE8NESS.

Water moves from one place to another by various means but the most common is the rivers which have been known to be diverted and the water directed to homes, farms, schools, businesses, industries, and many other places the water will be needed. As the water moves along the rivers, the water helps in nourishing the ecosystem and it provides a habitat for different organisms. The rivers, creeks, and wetlands are very essential to nature.

These natural environments make town look livelier and they essentially provide a place where individuals can relax, unwind, and connect with the natural environment. For individuals or groups such as the aboriginal people or the Amazonians the healthy rivers are seed for spiritual, physical, and cultural activities. When a river is lively, productive, and/or robust as its impact is felt wat beyond the riverbank (Figure 3.7) (Bailey, 2017).

Water has been known to have distinct properties and these properties are critical to life on earth. The water carries out different roles in and around the human body, and it erects in the body to allow for replication. On earth, all forms of life at one point in their lives or on their day-to-day activities they will depend on water. In essence metabolisms, are sum total to catabolism and anabolism. In the process of anabolism, water is removed from molecules so as to grow larger molecules such as starch, proteins for storage of fuel and information. In the other process of catabolism, water is used to break bonds so that smaller molecules can be generated. Without water these processes cannot occur. (Zhang, 2014).

In the natural environment it is known that there are two types of food synthesis, i.e., photosynthesis, and chemosynthesis and in these two they will need water in order for them to take place. In order for photosynthesis to take place, there are requirements that need to be present for it to take place. Water, sunlight, and carbon dioxide need to be present. During this process, the photosynthetic cells use the energy from the sun to split the water molecules to get hydrogen and oxygen. The hydrogen combines with carbon dioxide to form glucose and release oxygen in the process.

In the ph. scale water is considered to be neutral, i.e., water is at number seven which is the midpoint. Acids like selenium are those that are above seven and those that are below seven are considered to be a base or another name is alkaline.

On the earth's surface water is filled with all kinds of living things. Scientists believe that all the earlier forms appeared in water and almost all fish if not all lie in water. There ae many other examples of animals that are found in water, e.g., dolphins, whales which are mammals but are known to spend their lives in water. Some animals such as the amphibians spend portions of their lives in water. There are also some plants that spend their lives in and on water such as algae, kelp, water lily, water lettuce and many others. Some plants such as planktons and phytoplankton are the basic foundation for the water ecosystem food chain. This is because the herbivore fish feed on the planktons and in turn, the carnivorous fish feed on the other

herbivore fish for food hence there is a full ecosystem in water and there is a point of one depending on the other directly and indirectly.

Aquatic vertebrates have to obtain oxygen from water in order for them to survive, organisms such as fish have gills instead of lungs but some such as the lungfish have both. Some animals that live on water such as the mammals that live in water, e.g., dolphins, otters, whales, and many others have to regularly surface in the water in order for them to breath then they dive back into the water (Figure 3.8).

Figure 3.8. Aquatic vertebrate. They need oxygen from water in order to be able to survive. Some regularly go to the surface to get some oxygen before retreating under water.

Source: Florida Poison Information Center-Tampa.

Many civilizations historically were established where there was water for example Mesopotamia which was established between two rivers, i.e., river Tigris and river Euphrates. In another civilized nation, the Egyptians established themselves along the river Nile. Another civilization the romans established along the river Tiber.

Water is one of the factors that controls biodiversity and how the different ecosystems are distributed. The different ecosystems include communities of plants, animals, and bacteria and how they are related to the physical and chemical environment. In the terrestrial ecosystems, the animals and plants that are found there vary and have adapted to varied availability of water. These organisms live in conditions where the water is varied throughout

the year. The water availability in these conditions is dependent on seasons which are divided into four; summer when the sun is present throughout the day and rain is less or very little hence animals will migrate over long distances to get water, in autumn the distribution of rain is average, during fall the weather is changing drastically in preparation for winter ad during this time leaves drop onto the ground and water is sometimes in plenty and during winter it is one of the harshest seasons as temperatures fall below 0°C and water falls from the sky in form of ice (Yu et al., 2013).

There are some regions that have two seasons, i.e., the wet and dry season and these are countries that are found along the equator. During the dry season, rain is scarce, some plants dry up, and some animals even die because of lack of water. During the wet seasons, the rains fall almost daily and this leads to a boom in the different lifeforms. This leads to growth of seeds from the ground and most animals give birth during this season as food is in plenty. A good example is the natural 8th wonder of the world, i.e., the wildebeest migration between Kenya and Tanzania. The wildebeests move from Tanzania's Serengeti national park when the food has become scarce. When food is depleted, they migrate in search of fresh grass. The animals then while in Kenya give birth and multiply.

Figure 3.9. The Okavango delta in Botswana provides water for many wild animals in the area.

Source: Worldatlas.com.

During this migration it provides food for other animals in the ecosystem as crocodiles get enough food to sustain the for months. As they graze and

feed in Kenya the grass in the Serengeti is given opportunity to grow and flourish. When the food in Kenya's Maasai Mara reserve is depleted, they return back to Serengeti and they continue with their cycle annually. This shows that water controls various behaviors of animals on earth (Figure 3.9).

In the desert environments, the conditions are very harsh because of lack of water and animals in these conditions have found ways to sustain themselves. They move at night to prevent exposure to too much heat during the day. They also depend on plants to get their water. In deserts such as the Kalahari deserts, some animals like the elephants have been known to travel for hundreds of kilometers to reach water reserves and eventually get to Okavango delta and the Limpopo River in order to get water. Some animals are found in tropical forests and in most of these forests, they flourish because they are evergreen which means they are green throughout the year. Most of these forests have very high canopies and this is because most of the trees are trying to reach to the sun. the conditions on the ground are that it is soaking wet from January to January and scientists and researchers agree that these areas are some of the wettest places on earth. These areas include the amazon and the tropical rainforest in Congo. The animals in these areas flourish because food is found throughout the year.

The rainforest environment is one of the most important ecosystems on earth as it absorbs most of the selenium and carbon dioxide produced by human beings and machines. These forests also produce huge amounts of oxygen, which is very important for animals and other living organisms on earth. The water that falls onto these forests across the year sustains the vegetation and in turn, the vegetation provides life to different organisms. The amazon, which is the largest rainforest on earth, has been added to the UNESCO sites that need to be protected because there has been encroachment by human beings and this if not regulated will bring a huge shift in the environment surrounding it and the earth as a whole. The forest gives rise to one of the largest rivers on earth. The Amazon River delivers millions and millions of gallons of water into the Atlantic Ocean. The water contains various nutrients which in turn sustains some of the animals and plants that live in the ocean. The water has minerals and nutrients, which provides nutrients and food to some living organisms (Figure 3.10) (Yang et al., 2008).

Figure 3.10. A flock of flamingos and heir young. They move to Lake Natron in Tanzania for this specific reason to lay eggs and raise their young.

Source: Birdlife International.

Water that contains soda ash is very rare but it rains at some point in time. A good example s in the lake natron where some plants grow under specific conditions and it provides nourishment for these flamingos. This leads to migration of flamingoes who migrate to this area to lay their eggs and raise their young. At some point, the water will begin dry up and the water because it contains a lot of salt it begins to evaporate and sat crystals will form. These conditions come every few years and cause unique occurrences and with such the different ecosystems and animals and/birds are sustained. Some seeds of some plants lie dormant in the soil for years as they wait for a specific precipitation event so that they can germinate.

Some aquatic ecosystems such as lakes, wetlands, and streams are very sensitive to changes in water quality and quantity. Most environmentalists and researchers depend on the quality and quantity of water to determine whether here have been any changes in the environment. When there are pollutants and toxic substances, i.e., selenium, in the environment they will eventually find their way into the water sources, this in turn will provide the relevant data that can be used to determine whether there has been a shift in toxicity. The toxic substances are especially harmful to living organisms and plants that live in water and if there are changes in behavior of animals, it shows there is something wrong with the water.

A good example is the global warming, which has led to a rise in water levels. The increase in global warming and release of greenhouse gases has

led to melting of the ice in the north and the South Pole. The rate of melting is alarming as this is increasing the sea level drastically and some scientists believe this can lead to an ice age. The melting ice in the north and South Pole has affected many animals including the polar bears that live in the ice and some of them are sometimes cut out of their habitat when they are late to return to their homes. This has led to some bears trying to adapt and live-in areas without ice for some months before it eventually cools and they can migrate again (Figure 3.11).

Figure 3.11. Melting ice in the North Pole, which is increasing the sea level as years, go by.

Source: The New York Times.

The wetlands are very vital ecosystem as they provide habitats for some birds, plants, and animals. The transitional areas, i.e., where the dry and wet lands meet help in reducing floods and help prevent water pollution. Areas that are flat when there is heavy rainfall it becomes a swamp. These areas also provide regions where animals and other living organisms can have huge amounts of nutrients.

Water has been known to shape the earth's surface; forming canyons, flood plains, watersheds, and terraces. All these have been brought about by the movement of water from one place to the next.

In the natural ecosystem rivers play a very important role. Recreational fishing, industries, agriculture public health and tourism all benefit from a river system that is robust. Water in the environment supports the health of the river, which in turn provides for the needs of human beings. Rivers provide human beings with fish. When a river is healthy and robust it will in turn support fishing activity. The water found in rivers when it is of the

best quality, flow, and connectivity is good fish will be found in abundance. Many countries value the fishing that is carried out in rivers and in countries such as Nigeria where the fishing rituals are always related to fertility while in the united although it is a first world country will attach high spiritual value to the fishing of salmon on the river Elwha (Figure 3.12).

Figure 3.12. The Argungu fishing festival that happens in Nigeria is an event that is done over four days and it has its cultural significance.

Source: The African Exponent.

In a country like Scotland, the fishing process will provide income and employment to the community that lives along the rivers. Although the fishing practices in the developed countries tend to have some regulation in the developing countries have decided to sacrifice their fishing activities to give way for infrastructural development which has greatly affected income for some of the native communities and it has led to poverty of the original inhabitants of the area. When rivers are left to run their course naturally without disturbance from artificial human disturbances there will be abundance of fish and these areas will eventually develop. Water is a habitat for most aquatic ecosystem including fish. Fish is a source of food for most individuals across the globe especially those that are stated in the marine centers. To ensure sustainability of the fish ecosystem, water needs to be protected and pollution controlled. As a matter of fact, mainlanders are so demanding fish in high amounts and therefore need protection (Wei et al., 2021).

In most countries they mostly depend on food derived from irrigated agriculture in order for them to be able to be food secure. Food that is grown

from irrigated farms are crucial in developing livelihoods and in turn, families can get revenue when they sell their produce. Irrigation offers a lot of benefits but this will all depend on the investor conducting the irrigation project. This is because the individual has to consider that there are other individuals that are dependent on the water from the river downstream. The individual has to stop use water at rate that neighbors and people downstream and the river itself are not affected by the diversion of some of the water. When too much water is abstracted, then the river will eventually degrade and this will affect the different ecosystems that are found along the river after the abstraction. It has been noted that individuals that live close to irrigation schemes have been affected by various diseases. Inputs that are added to ensure proper growth of plants affect water. Pesticides, herbicides, and fertilizer all make their way into water and cause pollution, which in turn leads to eutrophication. With the changing environmental climate, the human world is left to fend for the already existing water bodies for agricultural purposes. Rain fed farming has always been the best chance for agriculture for a very long time and is the natural way in which water gets to the soil.

With rainfall, it is less likely that there are cases of food contamination but with its dependence, individuals can face shortages of water when there is reduced rainfall. Artificial application of water on the other hand is a safe method but is known to increase the risk of contamination. Irrigation is an artificial application of water in which individuals can use a number of methods including pumps, sprays, and tubes. They are normally used in areas where there is shortage of rainfall, during dry periods and when drought is expected. There are different types of irrigation systems such as the surface irrigation where water is distributed over and across land by gravity. In this case, there is no mechanical pump involved. Localized irrigation is the other system of irrigation where water is distributed under lower pressure using a piped network and is applied to each and every plant.

Drip irrigation is the other system of irrigation where the drops of water are delivered at or near the roots of the plant. With this kind of irrigation, evaporation, and runoff are normally minimized. The other is sprinkler irrigation where the water is distributed overhead by the use of high-pressure sprinklers or guns from a point centrally located in the farm. Center pivot irrigation is one in which water is distributed through a system of sprinklers that are made possible by wheeled towers that are made in a circular pattern. Lateral circulate irrigation is whereby Water is shipped thru a chain of pipes, every with a wheel and a fixed of sprinklers, which can be circled

either by means of hand or with a purpose-constructed mechanism. The sprinklers circulate a positive distance throughout the sphere after which want to have the water hose reconnected for the subsequent distance. This machine has a tendency to be much less steeply priced however calls for extra hard work than others. Another involves the Sub-irrigation system in which Water is shipped throughout land by means of elevating the water table, through a machine of pumping stations, canals, gates, and ditches. This kind of irrigation is simplest in regions with excessive water tables. In addition, there is Manual irrigation in which Water is shipped throughout land through guide hard work and watering cans. This machine may be very hard work intensive and very expensive (Wadhwani et al., 2016).

Many countries depend on electricity which in most of them they are generated from hydroelectric power plants. For hydroelectric power to be generated there has to be sufficient flow of water and the sediment has to be controlled but most of the power plants do not depend on the quality of water. In essence, an unhealthy river can still produce electric power. When hydroelectric power is to be developed the implications are social economic and also environmental. Water is normally seen to move in a vast global cycle, which then evaporates, from the lakes and ocean, forms clouds, which then precipitates to form-to-form rain or snow. They then flow back to the oceans and the seas. The energy that is brought about by this cycle is normally driven by the sun can be tapped to produce electricity or for mechanical tasks. Hydropower uses fuel, which is water, which is normally neither reduced nor used up in the process. Water cycle is an endless aspect and a constantly recharging system. Flowing water is normally captured and turned into electricity and is normally called hydroelectric power or hydropower. There is a number hydroelectric facility powered by kinetic energy by flowing water as it moves downstream. The turbines and generators are crucial in converting energy to electricity, which is then fed o the electrical grid, which is used in homes, businesses, and by the industry.

The power plants affect the biodiversity of an area. The power plants create large dams which in turn changes the landscape of an area and the living organisms found in the area will eventually migrate due to the change in environmental and favorable conditions. The river after the dam will be affected as most of the time the water leaving the dam will always be regulated and this will affect the activities that are carried out downstream. The fishing activities are the most affected in this instance, the plants that grow downstream will also be affected as most of the time there is inconsistency in the supply of water. With all these the habitats and

ecosystems that are found downstream will be affected and there will be changes and they will be drastic (Figure 3.13).

Figure 3.13. The Itaipu dam on the Brazil-Paraguay border led to the loss of 70% of the biodiversity in the area.

Source: Wikipedia.

A good example of effects of dams is in Europe. Rivers need to have continuity in order for them to offer complex life cycles of many living organisms that stay in water. With barriers such as dams, they have greatly affected natural flow of rivers. In Europe lone there have recorded up to 630,000 barriers that are blocking rivers. Some scientists believe that rivers carry sediments downstream and some of these sediments feed fish and when the sediments are stopped from flowing down freely this means the fish are starved and this will lead to a dead river. The dams have also been known to cut off the natural animal corridors, which simply means animals can no longer migrate. When plants downstream do not get the deserved water, it needs it may lead to extinction of some species because of degradation of their natural habitat. The Itaipu dam which was constructed in the border of Brazil and Paraguay in the 1970s and 1980s had a great impact on the biodiversity of the area. Up to 70% of biodiversity in the area was lost. Another dam constructed in the amazon, i.e., Tucurui dam, led to a drop of 60% productivity of fish.

A study that was conducted on the Mekong River, which is found in Asia, shows that there has been almost 40% drop in fish populations due to the construction of dams across the river (Ali et al., 2021).

The dams that are constructed in tropical forests collect a lot of water, which means the water accumulates to form mega dams, and in turn, some form very large lakes. This in turn destroys forests that act as carbon sinks. This is the short-term effect of the dam but in the end, the water level will also be affected as most of the forests attract rain, which in turn fills the dam. The changes in the tropical rainforests leads to enormous climate change which leads to prolonged drought, which will lead to less water also in the dams.

Oceans are the largest holders of water on earth as it holds 97% of the earth's water. They are regarded as the heart of the planet (Figure 3.14).

Figure 3.14. The blue whale, which is the largest animal on earth lives in the ocean.

Source: World Wildlife Fund.

Plants in the ocean such as the Posidonia produce up to 70% of the oxygen that living organisms use. They are also home to some of the largest creature at present to roam the earth. Creature such the humpback whale, the sperm whale, and the blue whale some of which have been known to grow up to 30 meters in length. The oceans help in the regulation of the earth's temperature as it has been known to carry the warm waters from the equator and the tropics to the poles and bring in the cold water. The rain that falls n land is known to have been carried by wind from the sea.

Rivers have been known to carry water and nutrients to almost all corners of the earth. They act as the drainage channels for surface water. Rivers play a very important role as they drain up to 75% of the surface water. The rivers

are also known to be habitats for some of the earths plants as some species of plants have been known to only grow on riverbanks. Many animals one way or another depends on rivers. In Africa, for example animals in the wild always drink their water from rivers and in the north animals such as bears depend on fish that they catch from rivers as their source of proteins. Rivers have also been known to be a means of transport, for example, the Mekong River in Asia is one of the major transport networks in some countries that are found along the river (Figure 3.15).

Figure 3.15. Mekong River in Asia. This river is a major transport network for countries found along the river.

Source: The New York Times.

In light of all the reasons in which water is needed, individuals need to understand the importance of preserving the quality of water. One way of doing it is by disposing all the harmful materials that may pollute water in a proper manner. One needs not dumb hazardous waste on the ground, which contaminates the soil on; contaminate ground water that is near the surface water. In addition to these individuals need to understand the quantity of pesticides and herbicides that the can use as they contain hazardous chemicals which pollute the environment. Another way to preserve water is by using less water. Many people waste water, which may expend each ground water and floor water supplies. Using much less water on each day foundation can help. Some easy approaches to do that can be helpful include repairing water leaks minimizing garden watering, amassing, and the use of rainwater, switching to water-green showerheads and rest room dams. Manage your wastewater properly is another way of ensuring that individuals preserve water. Never place dangerous contaminants into toilets, sinks or sewers. In

addition, when you have a septic gadget at your property or cottage, preserve it maintained and well working. One needs to take steps at their homes given the fact that there are many stuffs one may do at home to preserve and shield water quality. Some of the few easy steps that can be taken include using non-poisonous cleaners and biodegradable soaps and detergents lessening or doing away with your use of fertilizers and other chemical compounds on lawns and gardens use de-icing salts conservatively at some stage in wintry weather (Wang et al., 2018).

CHAPTER 4

PROPERTIES OF SELENIUM

CONTENTS

4.1. INTRODUCTION

Selenium is a synthetic component with the image Se and atomic number 34. It is a nonmetal (all the more seldom thought to be a metalloid) with properties that are middle between the components above and beneath in the intermittent table, sulfur, and tellurium, and furthermore has similitudes to arsenic. It once in a while happens in its basic state or as unadulterated metal mixtures in the Earth's outside. Selenium—from Ancient Greek σελήνη (sel ḗnē) "Moon"-was found in 1817 by Jöns Jacob Berzelius, who noticed the similitude of the new component to the recently found tellurium (named for the Earth).

Jacob Berzelius (20 August 1779–7 August 1848) was a Swedish physicist. Berzelius is thought of, alongside Robert Boyle, John Dalton, and Antoine Lavoisier, to be one of the originators of present-day chemistry. Berzelius turned into an individual from the Royal Swedish Academy of Sciences in 1808 and served from 1818 as its central functionary. He is referred to in Sweden as the "Father of Swedish Chemistry." Berzelius Day is commended on 20 August to pay tribute to him (Figure 4.1).

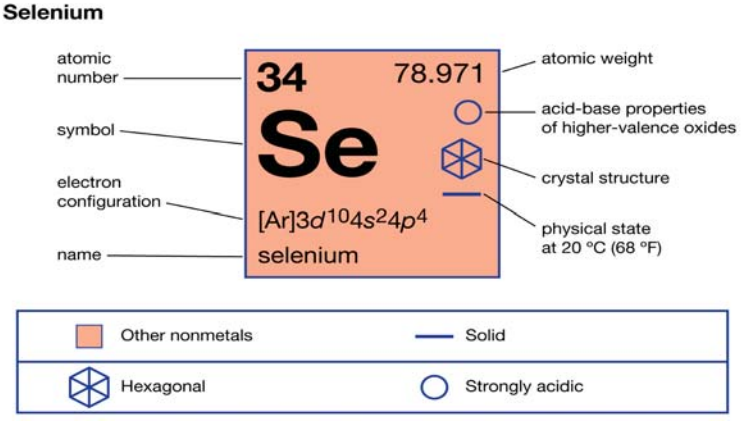

Figure 4.1. Selenium on the periodic table.

Source: https://www.britannica.com/science/selenium.

Despite the fact that Berzelius started his vocation as a doctor, his suffering commitments were in the fields of electrochemistry, substance holding and stoichiometry. Specifically, he is noted for his assurance of nuclear loads and his tests that prompted a more complete comprehension of the standards of stoichiometry, which is the part of science relating to

the quantitative connections between components in substance mixtures and compound responses and that these happen in unequivocal extents. This agreement came to be known as the "law of constant proportions."

Selenium is found in metal sulfide minerals, where it halfway replaces the sulfur. Financially, selenium is delivered as a result in the refining of these metals, regularly during creation. Minerals that are unadulterated selenide or selenate compounds are known however uncommon. The main business utilizes for selenium today are glassmaking and shades. Selenium is a semiconductor and is utilized in photocells. Applications in gadgets, once significant, have been generally supplanted with silicon semiconductor gadgets. Selenium is as yet utilized in a couple of kinds of DC power flood defenders and one sort of fluorescent quantum speck (Vogel et al., 2018).

Quantum specks (QDs) are semiconductor particles a couple of nanometers in size, having optical and electronic properties that contrast from bigger particles because of quantum mechanics. They are a focal theme in nanotechnology. At the point when the quantum dabs are enlightened by UV light, an electron in the quantum dab can be eager to a condition of higher energy. On account of a semiconducting quantum spot, this cycle relates to the progress of an electron from the valence band to the conductance band. The energized electron can drop once again into the valence band delivering its energy by the emanation of light. This light discharge (photoluminescence) is delineated in Figure 4.2 on the right. The shade of that light relies upon the energy distinction between the conductance band and the valence band.

Figure 4.2. Fluorescent solutions under UV-light. Absorbed photons are rapidly re-emitted under longer electromagnetic wavelengths.

Source: https://en.wikipedia.org/wiki/Photoluminescence.

In spite of the fact that follow measures of selenium are fundamental for cell work in numerous creatures, including people, both essential selenium

and (particularly) selenium salts are harmful in even little portions, causing selenosis. Selenium is recorded as a fixing in numerous multivitamins and other dietary enhancements, just as in newborn child equation, and is a part of the cell reinforcement proteins glutathione peroxidase (GPx) and thioredoxin reductase (which by implication decrease certain oxidized particles in creatures and a few plants) just as in three deiodinase chemicals. Selenium necessities in plants contrast by species, for certain plants requiring moderately enormous sums and others evidently requiring none.

4.2. QUALITIES

Selenium shapes a few allotropes that interconvert with temperature changes, contingent fairly upon the pace of temperature change. At the point when ready in substance responses, selenium is normally an indistinct, block red powder. When quickly liquefied, it shapes the dark, glassy structure, generally sold monetarily as globules. The design of dark selenium is unpredictable and complex and comprises of polymeric rings with up to 1,000 molecules for each ring. Dark Se is a fragile, shiny strong that is marginally solvent in CS2. After warming, it relaxes at 50°C and converts to dim selenium at 180°C; the change temperature is diminished by the presence of incandescent light and amines.

Allotropy or allotropism (from Ancient Greek ἄλλος (allos) 'other,' and τρόπος (tropos) 'way, structure') is the property of some synthetic components to exist in at least two distinct structures, in a similar actual state, known as allotropes of the components. Allotropes are diverse underlying alterations of an element the particles of the component are reinforced together in an alternate way. For instance, the allotropes of carbon incorporate precious stone (the carbon iotas are fortified together in a tetrahedral cross section game plan), graphite (the carbon particles are reinforced together in sheets of a hexagonal grid), graphene (single sheets of graphite), and fullerenes (the carbon molecules are fortified together in circular, cylindrical, or ellipsoidal developments) (Teng et al., 2015).

The term allotropy is utilized for components just, not for compounds. The broader term, utilized for any compound, is polymorphism, in spite of the fact that its utilization is normally confined to strong materials like gems. Allotropy alludes just to various types of a component inside a similar actual stage (the condition of issue, like a strong, fluid or gas). The contrasts between these conditions of issue would not the only one comprise instances

of allotropy. Allotropes of substance components are much of the time alluded to as polymorphs or as periods of the component (Figure 4.3).

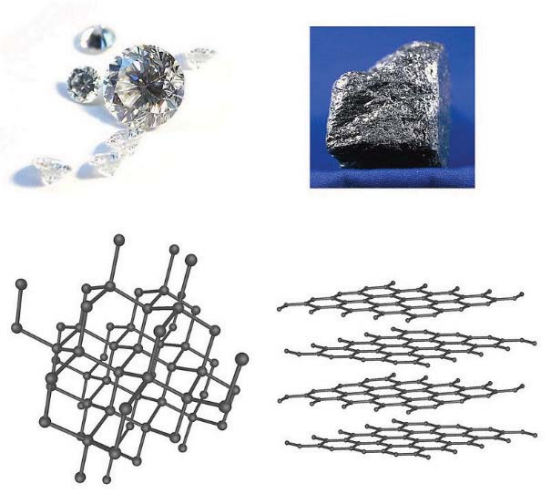

Figure 4.3. Diamond and graphite are two allotropes of carbon: Pure forms of the same element that differ in crystalline structure.

Source: https://en.wikipedia.org/wiki/Allotropy.

For certain components, allotropes have diverse sub-atomic formulae or distinctive translucent designs, just as a distinction in actual stage; for instance, two allotropes of oxygen (dioxygen, O_2, and ozone, O_3) can both exist in the strong, fluid, and vaporous states. Different components do not keep up with particular allotropes in various actual stages; for instance, phosphorus has various strong allotropes, which all return to a similar P4 structure when liquefied to the fluid state.

The red α, β, and γ structures are created from arrangements of dark selenium by fluctuating the vanishing pace of the dissolvable (typically CS2). They all have moderately low, monoclinic gem balances and contain almost indistinguishable puckered Se8 rings with various plans, as in sulfur. The pressing is generally thick in the α structure. In the Se8 rings, the Se-Se distance is 233.5 pm and Se-Se-Se point is 105.7°. Other selenium allotropes may contain Se6 or Se7 rings.

The most steady and thick type of selenium is dark and has a hexagonal precious stone grid comprising of helical polymeric chains, where the Se-

Se distance is 237.3 pm and Se-Se-Se point is 130.1°. The base distance between chains is 343.6 pm. Dim Se is framed by gentle warming of different allotropes, by lethargic cooling of liquid Se, or by gathering Se fume just beneath the dissolving point. Though other Se structures are encasings, dim Se is a semiconductor showing obvious photoconductivity. In contrast to different allotropes, it is insoluble in CS2. It opposes oxidation via air and is not assaulted by nonoxidizing acids. With solid diminishing properties, it structures polyselenides. Selenium does not display the progressions in thickness that sulfur goes through when continuously warmed.

4.3. OPTICAL PROPERTIES

Attributable to its anything but a photoconductor in level board x-beam finders (see beneath), the optical properties of undefined selenium (α-Se) slim movies have been the subject of exceptional examination.

4.3.1. Isotopes

Selenium has seven normally happening isotopes. Five of these, 74Se, 76Se, 77Se, 78Se, 80Se, are steady, with 80Se being the most plentiful (49.6% regular plenitude). Likewise, normally occurring is the extensive early-stage radionuclide 82Se, with a half-life of 9.2 × 1019 years. The non-early-stage radioisotope 79Se additionally happens in minute amounts in uranium metals as a result of atomic parting. Selenium likewise has various temperamental manufactured isotopes going from 64Se to 95Se; the most steady are 75Se with a half-existence of 119.78 days and 72Se with a half-existence of 8.4 days. Isotopes lighter than the steady isotopes fundamentally go through beta in addition to rot to isotopes of arsenic, and isotopes heavier than the steady isotopes go through beta less rot to isotopes of bromine, with some minor neutron discharge branches in the heaviest known isotopes (Figure 4.4) (Suazo-Hernández et al., 2019).

In geochemistry, geophysics, and atomic material science, early-stage nuclides, otherwise called early-stage isotopes, are nuclides found on Earth that have existed in their present structure since before Earth was framed. Early-stage nuclides were available in the interstellar medium from which the nearby planetary group was shaped, and were framed in, or after, the Big Bang, by nucleosynthesis in stars and supernovae followed by mass discharge, by astronomical beam spallation, and conceivably from different cycles. They are the stable nuclides in addition to the extensive part of

radionuclides getting by in the early-stage sun-based cloud through planet growth until the present. Around 200 and 86 such nuclides are known.

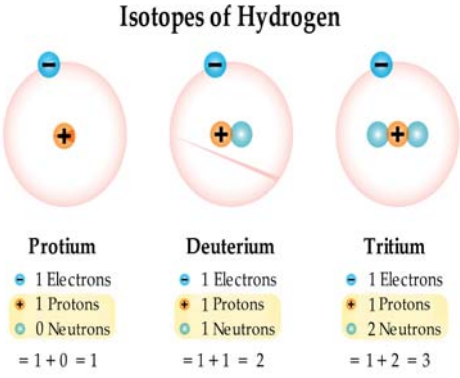

Figure 4.4. Isotopes.

Source: https://www.shutterstock.com/search/isotopes.

4.3.2. Substance Compounds

Selenium compounds regularly exist in the oxidation states –2, +2, +4, and +6. The oxidation state, once in a while alluded to as oxidation number, portrays the level of oxidation (loss of electrons) of a molecule in a substance compound.

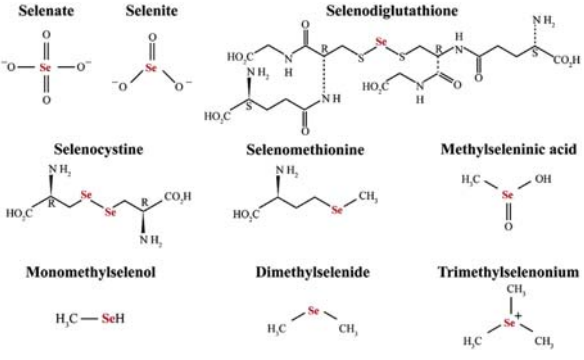

Figure 4.5. Selenium compounds.

Source: https://www.researchgate.net/publication/233888974_Methylselenol_Formed_by_Spontaneous_Methylation_of_Selenide_Is_a_Superior_Selenium_Substrate_to_the_Thioredoxin_and_Glutaredoxin_Systems/figures?lo=1&utm_source=google&utm_medium=organic.

Adroitly, the oxidation state, which might be positive, negative or zero, is the theoretical charge that a molecule would have if all bonds to iotas of various components were 100% ionic, with no covalent segment. This is never precisely valid for genuine bonds (Figure 4.5).

4.3.3. Chalcogen Compounds

Selenium structures two oxides: selenium dioxide (SeO_2) and selenium trioxide (SeO_3). Selenium dioxide is framed by the response of essential selenium with oxygen:

$$Se8 + 8O_2 \rightarrow 8SeO_2$$

Selenium compounds regularly exist in the oxidation states –2, +2, +4, and +6. Strong SeO_2 is a one-dimensional polymer, the chain comprising of rotating selenium and oxygen molecules. Every Se particle is pyramidal and bears a terminal oxide bunch. The crossing over Se-O bond lengths is 179 pm and the terminal Se-O distance is 162 pm. The relative stereochemistry at Se substitutes along the polymer chain (syndiotactic). In the gas stage selenium dioxide is available as dimers and other oligomeric species, at higher temperatures it is monomeric. The monomeric structure receives a bowed construction basically the same as that of sulfur dioxide with a bond length of 161 pm. The dimeric structure has been confined in a low temperature argon lattice and vibrational spectra show that it has a centrosymmetric seat form. Dissolution of SeO_2 in selenium oxydichloride give the trimer [Se(O) O]3. Monomeric SeO_2 is a polar particle, with the dipole snapshot of 2.62 D pointed from the midpoint of the two oxygen iotas to the selenium molecule (Song et al., 2021).

The strong sublimes promptly. At extremely low focuses the fume has a disgusting scent, taking after rotted horseradishes. At higher fixations, the fume has a smell taking after horseradish sauce and can consume the nose and throat on inward breath. Though SO_2 will in general be atomic and SeO_2 is a one-dimensional chain, TeO_2 is a cross-connected polymer.

SeO_2 is viewed as an acidic oxide: it disintegrates in water to shape selenous corrosive. Regularly the terms selenous corrosive and selenium dioxide are utilized conversely. It responds with the base to shape selenite salts containing the SeO^{2-}_3 anion.

Selenium trioxide is the inorganic compound with the equation SeO_3. It is white, hygroscopic strong. It is anything but an oxidizing property and a Lewis corrosive. It is of scholarly interest as a forerunner to Se(VI) accumulates.

It is a polymeric strong that structures monomeric SeO_2 particles in the gas stage. It breaks down in water to frame selenous corrosive, H_2SeO_3. Selenous corrosive is comparable to sulfurous corrosive, however it is all the more promptly disconnected. Selenous corrosive is effectively shaped upon the expansion of selenium dioxide to water. As a translucent strong, the compound can be viewed as pyramidal atoms that are interconnected with hydrogen bonds. In arrangement it is a diprotic acid Selenous corrosive can likewise be made straight by oxidizing natural selenium with nitric corrosive:

$3Se + 4HNO_3 + H_2O \rightarrow 3H_2SeO_3 + 4NO$

In contrast to sulfur, which frames a steady trioxide, selenium trioxide is thermodynamically temperamental and breaks down to the dioxide over 185°C:

$2SeO_3 \rightarrow 2SeO_2 + O_2$ ($\Delta H = –54$ kJ/mol)

Selenium trioxide is created in the research center by the response of anhydrous potassium selenate (K_2SeO_4) and sulfur trioxide (SO_3). Potassium selenate, K_2SeO_4, is a scentless, white strong that structures as the potassium salt of selenic corrosive. It is utilized in photography.

Salts of selenous corrosive are called selenites. These incorporate silver selenites (Ag_2SeO_3) and sodium selenite (Na_2SeO_3).

Hydrogen sulfide responds with fluid selenous corrosive to create selenium disulfide:

$H_2SeO_3 + 2H_2S \rightarrow SeS_2 + 3H_2O$

Selenium disulfide comprises of 8-membered rings. It has a surmised piece of SeS_2, with singular rings fluctuating in creation, like Se4S4 and Se2S6. Selenium disulfide has been utilized in cleanser as an antidandruff property, an inhibitor in polymer science, a glass color, and a diminishing property in firecrackers (Singh et al., 2021).

Selenium trioxide might be integrated by getting dried out selenic corrosive, H_2SeO_4, which is itself created by the oxidation of selenium dioxide with hydrogen peroxide:

$SeO_2 + H_2O_2 \rightarrow H_2SeO_4$

Hot, concentrated selenic corrosive can respond with gold to frame gold(III) selenate.

4.3.4. Halogen Compounds

Iodides of selenium are not notable. An iodide particle is the particle I^-. Mixtures with iodine in proper oxidation state –1 are called iodides. In regular day to day existence, iodide is most normally experienced as a part of iodized salt, which numerous administrations order. Around the world, iodine insufficiency influences 2 billion individuals and is the main preventable reason for scholarly incapacity (Figure 4.6).

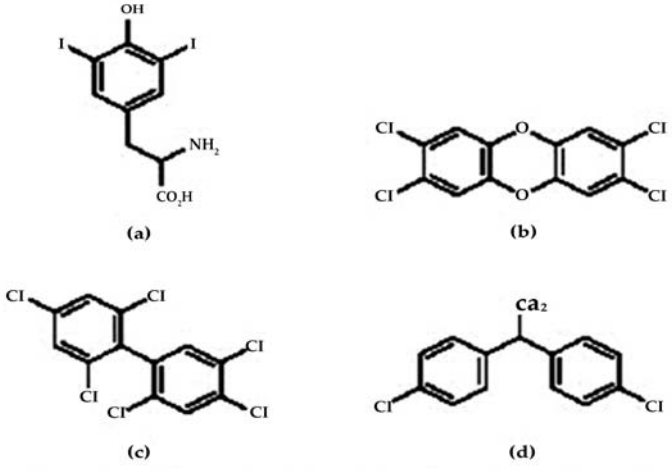

Figure 4.6. Four representative organohalogens: (a) a thyroid hormone; (b) "dioxin" (2,3,7,8-tetrachlorodibenzo-p-dioxin); (c) a polychlorinated biphenyl (PCB); (d) DDT (dichlorodiphenyltrichloroethane).

Source: http://www.chemistryexplained.com/Ny-Pi/Organic-Halogen-Compounds.html.

Iodide is one of the biggest monatomic anions. It is anything but a sweep of around 206 picometers. For correlation, the lighter halides are extensively more modest: bromide (196 pm), chloride (181 pm), and fluoride (133 pm). To a limited extent in light of its size, iodide shapes moderately powerless securities with most components.

Most iodide salts are dissolvable in water, yet frequently less so than the connected chlorides and bromides. Iodide, being huge, is less hydrophilic contrasted with the more modest anions. One outcome of this is that sodium iodide is exceptionally dissolvable in $(CH_3)_2CO$, though sodium chloride isn't. The low dissolvability of silver iodide and lead iodide mirrors the covalent person of these metal iodides. A test for the presence of iodide

particles is the development of yellow accelerates of this endless supply of an answer of silver nitrate or lead(II) nitrate (Singh et al., 2015).

The solitary stable chloride is selenium monochloride (Se_2Cl_2), which may be otherwise called selenium(I) chloride; the relating bromide is likewise known. These species are fundamentally undifferentiated from the comparing disulfur dichloride. Selenium dichloride is a significant reagent in the planning of selenium compounds (for example the planning of Se7). It is ready by treating selenium with sulfuryl chloride (SO_2Cl_2). Selenium responds with fluorine to shape selenium hexafluoride:

$Se8 + 24\ F2 \rightarrow 8SeF_6$

In examination with its sulfur partner (sulfur hexafluoride), selenium hexafluoride (SeF_6) is more receptive and is a harmful aspiratory aggravation. A portion of the selenium oxyhalides, for example, selenium oxyfluoride ($SeOF_2$) and selenium oxychloride ($SeOCl_2$) have been utilized as strength solvents.

4.3.5. Selenides

Closely resembling the conduct of other chalcogens, selenium structures hydrogen selenide, H_2Se. It is a firmly odiferous, poisonous, and dreary gas. It is more acidic than H_2S. In arrangement it ionizes to HSe^-. The selenide dianion Se_2^- structures an assortment of mixtures, including the minerals from which selenium is acquired monetarily. Illustrative selenides incorporate mercury selenide (HgSe), lead selenide (PbSe), zinc selenide (ZnSe), and copper indium gallium diselenide ($Cu(Ga,In)Se_2$). These materials are semiconductors. With profoundly electropositive metals, like aluminum, these selenides are inclined to hydrolysis:

$Al_2Se_3 + 3H_2O \rightarrow Al_2O_3 + 3H_2Se$

Salt metal selenides respond with selenium to frame polyselenides, Se_2-n, which exist as chains (Figure 4.7).

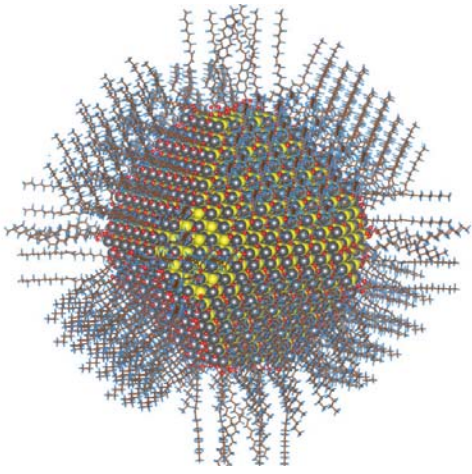

Figure 4.7. Core shell sulfide/selenide quantum dot.

Source: https://en.wikipedia.org/wiki/Selenide.

4.4. DIFFERENT MIXTURES

Tetraselenium tetranitride, Se_4N_4, is a hazardous orange compound practically equivalent to tetrasulfur tetranitride (S_4N_4). It tends to be blended by the response of selenium tetrachloride ($SeCl_4$) with [((CH$_3$)3Si)2N]2Se. Selenium responds with cyanides to yield selenocyanates: 8KCN + Se_8 → 8KSeCN.

4.4.1. Organoselenium Compounds

Selenium, particularly in the II oxidation state, structures stable bonds to carbon, which are primarily similar to the relating organosulfur compounds. Particularly normal are selenides (R_2Se, analogs of thioethers), diselenides (R_2Se_2, analogs of disulfides), and selenols (RSeH, analogs of thiols). Delegates of selenides, diselenides, and selenols incorporate individually selenomethionine, diphenyldiselenide, and benzeneselenol. The sulfoxide in sulfur science is addressed in selenium science by the selenoxides (equation RSe(O)R), which are intermediates in natural combination, as shown by the selenoxide disposal response. Reliable with patterns demonstrated by the twofold security rule, selenoketones, R(C=Se)R, and selenaldehydes, R(C=Se)H, are infrequently noticed (Figure 4.8) (Sabuda et al., 2020).

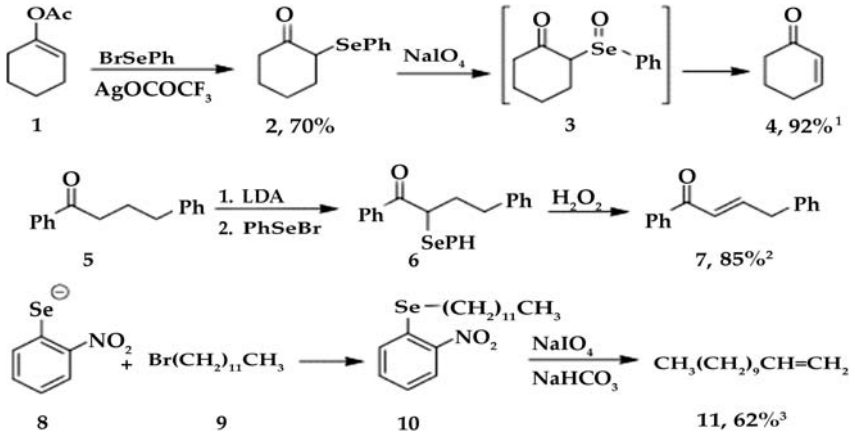

Figure 4.8. Organoselenium compounds.

Source: https://www.sciencedirect.com/topics/chemistry/organoselenium-compound.

4.4.2. Organoselenium Science

Organoselenium compounds (or seleno-natural) are substance compounds containing carbon-to-selenium synthetic bonds. Organoselenium science is the comparing science investigating their properties and reactivity. Selenium has a place with oxygen and sulfur to the gathering 16 components or chalcogens, and likenesses in science are not out of the ordinary. Organoselenium compounds are found at follow levels in encompassing waters, soils, and sediments.

Selenium can exist with oxidation state –2, +2, +4, +6. Se(II) is the predominant structure in organoselenium science. Down the gathering 16 section, the bond strength turns out to be progressively more vulnerable (234 kJ/mol for the C–Se bond and 272 kJ/mol for the C–S bond) and the bond lengths longer (C–Se 198 pm, C–S 181 pm and C–O 141 pm). Selenium compounds are more nucleophilic than the relating sulfur compounds and furthermore more acidic. The pKa upsides of XH2 are 16 for oxygen, 7 for sulfur and 3.8 for selenium. As opposed to sulfoxides, the comparing selenoxides are temperamental within the sight of β-protons and this property is used in numerous natural responses of selenium, eminently in selenoxide oxidations and in selenoxide disposals (Raymond and Ralston, 2020). The first organoselenium compound to be confined was diethyl selenide in 1836 (Figure 4.9).

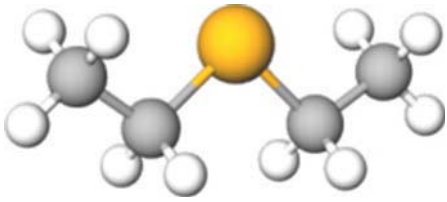

Figure 4.9. 3D model of diethyl selenide.

Source: https://en.wikipedia.org/wiki/Diethyl_selenide#/media/File:Et2se3d.png.

4.5. ORGANOSELENIUM COMPOUNDS IN NATURE

Selenium, as organoselenium compounds, is a fundamental micronutrient whose nonattendance from the eating routine causes cardiovascular muscle and skeletal brokenness. Organoselenium compounds are needed for cell guard against oxidative harm and for the right working of the insusceptible situation. They may likewise assume a part in avoidance of untimely maturing and malignant growth. The wellspring of Se utilized in biosynthesis is selenophosphate.

Glutathione oxidase is a chemical with a selenol at its dynamic site. Organoselenium compounds have been found in higher plants. For, endless supply of garlic utilizing the method of superior fluid chromatography joined with inductively coupled plasma mass spectrometry (HPLC-ICP-MS), it was discovered that γ-glutamyl-Se-methylselenocysteine was the significant Se-containing segment, alongside lesser measures of Se-methylselenocysteine. Follow amounts of dimethyl selenide and allyl methyl selenide are found in human breath in the wake of devouring crude garlic.

4.5.1. Selenocysteine and Selenomethionine

Selenocysteine, called the 21st amino corrosive, is fundamental for ribosome-coordinated protein amalgamation in certain organic entities. In excess of 25 selenium-containing proteins (selenoproteins) are presently known. Most selenium-subordinate chemicals contain selenocysteine, which is identified with cysteine simple yet with selenium supplanting sulfur. This amino corrosive is encoded in an extraordinary way by DNA (Figure 4.10).

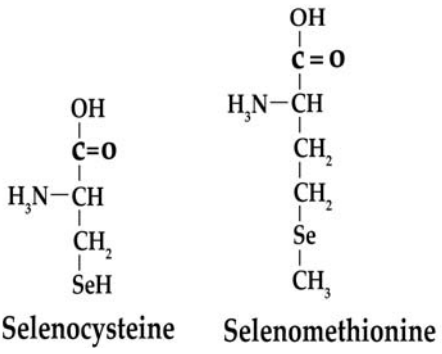

Figure 4.10. Selenocysteine and selenomethionine.

Source: https://www.sciencedirect.com/topics/neuroscience/selenomethionine.

Selenomethionine is a selenide-containing amino corrosive that likewise happens normally, yet is created by post-transcriptional change.

4.6. HISTORY OF SELENIUM

Selenium (Greek σελήνη selene signifying "Moon") was found in 1817 by Jöns Jacob Berzelius and Johan Gottlieb Gahn. The two physicists possessed a science plant close to Gripsholm, Sweden, delivering sulfuric corrosive by the lead chamber measure. The pyrite from the Falun Mine made a red hasten leading the pack chambers which was ventured to be an arsenic compound, so the pyrite's utilization to make corrosive was stopped. Berzelius and Gahn needed to utilize the pyrite and they additionally saw that the red hastens radiated a smell like horseradish when consumed. This smell was not regular of arsenic, yet a comparable scent was known from tellurium compounds. Consequently, Berzelius' first letter to Alexander Marcet expressed that this was a tellurium compound. Notwithstanding, the absence of tellurium compounds in the Falun Mine minerals at last drove Berzelius to reanalyze the red hasten, and in 1818 he composed a second letter to Marcet portraying a recently discovered component like sulfur and tellurium. As a result of its similitude to tellurium, named for the Earth, Berzelius named the new component after the Moon (Papp et al., 2010).

In 1873, Willoughby Smith tracked down that the electrical opposition of dark selenium was reliant upon the encompassing light. This prompted it is anything but a cell for detecting light. The principal business items utilizing selenium were created by Werner Siemens during the 1870s. The

selenium cell was utilized in the photophone created by Alexander Graham Bell in 1879. Selenium sends an electric flow corresponding to the measure of light falling on its surface. This marvel was utilized in the plan of light meters and comparable gadgets. Selenium's semiconductor properties tracked down various different applications in gadgets. The advancement of selenium rectifiers started during the mid-1930s, and these supplanted copper oxide rectifiers since they were more effective. These endured in business applications until the 1970s, following which they were supplanted with more affordable and surprisingly more effective silicon rectifiers.

Selenium came to clinical notification later as a result of its harmfulness to modern laborers. Selenium was additionally perceived as a significant veterinary poison, which is found in creatures that have eaten high-selenium plants. In 1954, the principal traces of explicit organic elements of selenium were found in microorganisms by natural chemist, Jane Pinsent. It was found to be fundamental for mammalian life in 1957. During the 1970s, it was demonstrated to be available in two autonomous arrangements of catalysts. This was trailed by the revelation of selenocysteine in proteins. During the 1980s, selenocysteine was demonstrated to be encoded by the codon UGA. The recoding instrument was worked out first in quite a while and afterward in warm blooded animals (see SECIS component).

4.7. EVENT

Local selenium in sandstone, from a uranium mine close to Grants, New Mexico. Local (i.e., basic) selenium is an uncommon mineral, which does not for the most part structure great precious stones, at the same time, when it does, they are steep rhombohedra or minuscule acicular (hair-like) gems. Disconnection of selenium is frequently muddled by the presence of different mixtures and components.

Selenium happens normally in various inorganic structures, including selenide, selenate, and selenite, yet these minerals are uncommon. The normal mineral selenite is not a selenium mineral, and contains no selenite particle, however is somewhat a sort of gypsum (calcium sulfate hydrate) named like selenium for the moon a long time before the revelation of selenium. Selenium is most regularly found as a pollutant, supplanting a little piece of the sulfur in sulfide minerals of numerous metals.

In living frameworks, selenium is found in the amino acids selenomethionine, selenocysteine, and methylselenocysteine. In these mixtures, selenium assumes a part similar to that of sulfur. Another normally

happening organoselenium compound is dimethyl selenide. Certain dirt is selenium-rich, and selenium can be bioconcentrated by certain plants. In soils, selenium regularly happens in solvent structures, for example, selenate (undifferentiated from sulfate), which are drained into streams effectively by overflow. Sea water contains huge measures of selenium (Figure 4.11).

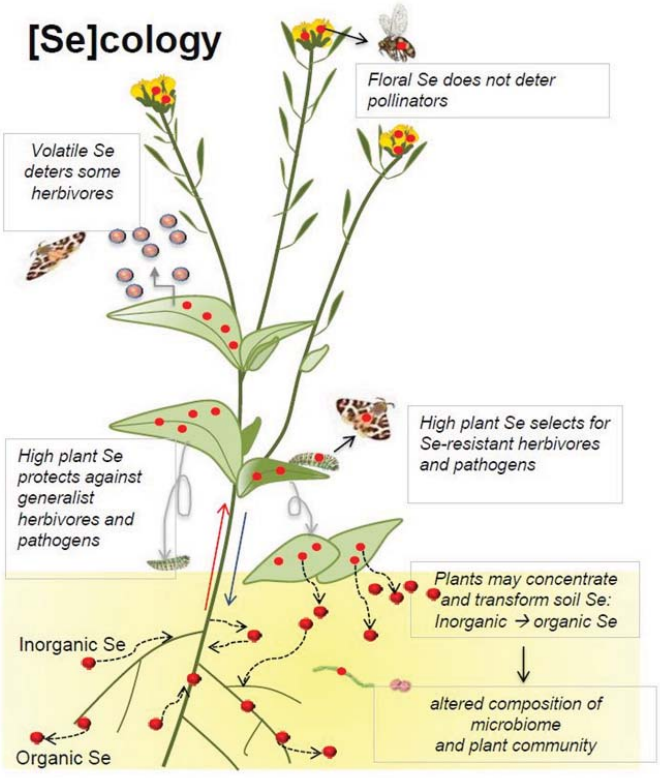

Figure 4.11. On the ecology of selenium accumulation in plants.

Source: https://www.mdpi.com/2223-7747/8/7/197/htm.

Anthropogenic wellsprings of selenium incorporate coal consuming, and the mining and purifying of sulfide minerals.

4.8. CREATION

Selenium is most normally created from selenide in numerous sulfide minerals, like those of copper, nickel, or lead. Electrolytic metal refining

is especially useful of selenium as a side-effect, acquired from the anode mud of copper treatment facilities. Another source was the mud from the lead offices of sulfuric corrosive plants, a cycle that is not, at this point utilized. Selenium can be refined from these muds by various strategies. Notwithstanding, most essential selenium comes as a side-effect of refining copper or delivering sulfuric corrosive. Since its innovation, dissolvable extraction (SX), and electrowinning (SX/EW) creation of copper delivers an expanding portion of the overall copper supply. These progressions the accessibility of selenium in light of the fact that solitary an equivalently little piece of the selenium in the mineral is filtered with the copper (Ojeda et al., 2020).

Dissolvable extraction and electrowinning (SX/EW) are a two-stage hydrometallurgical measure that first concentrates and redesigns copper particles from poor quality drain arrangements into a dissolvable containing a compound that specifically responds with and ties the copper in the dissolvable. The copper is extricated from the dissolvable with solid fluid corrosive which then, at that point stores unadulterated copper onto cathodes utilizing an electrolytic system (EW).

Fluid extraction (LLE), otherwise called SX and dividing, is a technique to isolate mixtures or metal edifices, in view of their overall solubilities in two diverse immiscible fluids, typically water (polar) and a natural dissolvable (non-polar). There is a net exchange of at least one animal varieties from one fluid into another fluid stage, by, and large from watery to natural. The exchange is driven by synthetic potential, for example when the exchange is finished, the general arrangement of substance parts that make up the solutes and the solvents are in a more steady setup (lower free energy). The dissolvable that is advanced in solute(s) is called remove. The feed arrangement that is exhausted in solute(s) is known as the raffinate. LLE is an essential procedure in substance research centers, where it is performed utilizing an assortment of mechanical assembly, from separatory pipes to countercurrent dissemination gear called blender settlers. This kind of cycle is ordinarily performed after a compound response as a feature of the work-up, frequently including an acidic work-up.

The term dividing is generally used to allude to the fundamental compound and actual cycles engaged with fluid extraction, yet on another perusing might be completely inseparable from it. The term SX can likewise allude to the detachment of a substance from a blend by specially dissolving that substance in an appropriate dissolvable. All things considered, a solvent compound is isolated from an insoluble compound or a complex matrix.

According to a hydrometallurgical viewpoint, SX is solely utilized in partition and cleaning of uranium and plutonium, zirconium, and hafnium, detachment of cobalt and nickel, division, and filtration of uncommon earth components and so on, its most prominent benefit being its capacity to specifically isolate out even very much like metals. One acquires high-immaculateness single metal streams on 'stripping' out the metal worth from the 'stacked' natural wherein one can accelerate or store the metal worth. Stripping is something contrary to extraction: Transfer of mass from natural to fluid stage (Lemaire et al., 2021).

LLE is likewise generally utilized in the creation of fine natural mixtures, the handling of aromas, the creation of vegetable oils and biodiesel, and other industries. It is among the most well-known beginning division methods; however, a few challenges bring about removing out firmly related practical gatherings.

Fluid extraction is conceivable in non-watery frameworks: In a framework comprising of a liquid metal in touch with liquid salts, metals can be separated from one stage to the next. This is identified with a mercury anode where a metal can be decreased, the metal will regularly then break up in the mercury to frame a blend that adjusts its electrochemistry significantly. For instance, it is feasible for sodium cations to be decreased at a mercury cathode to shape sodium blend, while at an idle anode (like platinum) the sodium cations are not diminished. All things being equal, water is diminished to hydrogen.

Hydrometallurgy is a procedure inside the field of extractive metallurgy, the getting of metals from their minerals. Hydrometallurgy include the utilization of fluid answers for the recuperation of metals from minerals, focuses, and reused or leftover materials. Processing strategies that supplement hydrometallurgy are pyrometallurgy, fume metallurgy, and liquid salt electrometallurgy. Hydrometallurgy is ordinarily partitioned into three general regions:

- Leaching;
- Solution fixation and sanitization; and
- Metal or metal compound recuperation.

SX/EW handling is most popular for its utilization by the copper business, where it represents 20% of overall creation, yet the innovation is likewise effectively applied to a wide scope of different metals including cobalt, nickel, zinc, and uranium. Modern creation of selenium generally includes the extraction of selenium dioxide from deposits got during the

cleaning of copper. Normal creation from the buildup then, at that point starts by oxidation with sodium carbonate to deliver selenium dioxide, which is blended in with water and fermented to frame selenous corrosive (oxidation step). Selenous corrosive is risen with sulfur dioxide (decrease venture) to give basic selenium.

Around 2,000 tons of selenium were delivered in 2011 around the world, for the most part in Germany (700 tons), Japan (750 tons), Belgium (200 tons), and Russia (140 tons), and the all-out holds were assessed at approximately 93,000 tons (US Geological Survey Mineral Resources Program, 2012; https://www.indexmundi.com/en/commodities/minerals/selenium_and_tellurium/selenium_and_tellurium_t6.html).

This information avoids two significant makers: the United States and China. A past sharp increment was seen in 2004 from $4–$5 to $27/lb. The cost was somewhat steady during 2004–2010 at about US $30 per pound (in 100-pound parts) yet expanded to $65/lb in 2011. The utilization in 2010 was isolated as follows: metallurgy-30%, glass fabricating-30%, horticulture-10%, synthetic substances and colors-10%, and hardware-10%. China is the prevailing purchaser of selenium at 1,500–2,000 tons/year.

4.9. APPLICATION

4.9.1. Composts

Specialists found that use of selenium compost to lettuce crops diminished the gathering of lead and cadmium. Peaches and pears given a foliar selenium shower contained more significant levels of selenium and furthermore remained firm and ready longer when away. In low dosages, selenium has shown a valuable impact on plant protection from different ecological pressure factors including dry season, UV-B, soil saltiness, and cold or hot temperatures. Nonetheless, it can harm plants at higher dosages (Figure 4.12).

Figure 4.12. Composting tips and strategies.

Source: https://www.ecofarmingdaily.com/build-soil/soil-inputs/compost/composting-tips-strategies-balanced-compost/.

Soil saltiness is the salt substance in the dirt; the way toward expanding the salt substance is known as salinization. Salts happen normally inside soils and water. Salination can be brought about by normal cycles, for example, mineral enduring or by the continuous withdrawal of a sea. It can likewise come to fruition through counterfeit cycles, for example, water system and street salt (Lenz and Lens, 2009).

4.9.2. Manganese Electrolysis

During the EW of manganese, the expansion of selenium dioxide diminishes the force important to work the electrolysis cells. China is the biggest purchaser of selenium dioxide for this reason. For each huge load of manganese, a normal 2 kg selenium oxide is utilized.

EW, additionally called electroextraction, is the electrodeposition of metals from their minerals that have been placed in arrangement by means of a cycle normally alluded to as draining. Electrorefining utilizes a comparable interaction to eliminate debasements from a metal. The two cycles use electroplating for a huge scope and are significant procedures for the conservative and clear decontamination of non-ferrous metals. The

subsequent metals are supposed to be electrowon. In EW, an electrical flow is passed from a dormant anode (oxidation) through a drain arrangement containing the broke up metal particles with the goal that the metal is recuperated as it is saved in an electroplating interaction onto the cathode (decrease). In electrorefining, the anode comprises of the polluted metal (e.g., copper) to be refined. The polluted metallic anode is oxidized and the metal disintegrates into arrangement. The metal particles move through the acidic electrolyte towards the cathode where the unadulterated metal is stored. Insoluble strong contaminations sedimenting beneath the anode frequently contain important uncommon components like gold, silver, and selenium.

4.9.3. Glass Creation

The biggest business utilization of Se, representing about half of utilization, is for the creation of glass. Se compounds present a red tone to glass. This shading counteracts the green or yellow colors that emerge from iron pollutions common for most glass. For this reason, different selenite and selenate salts are added. For different applications, a red tone might be wanted, created by combinations of CdSe and CdS. (Lampis et al., 2014).

4.9.4. Combinations

Selenium is utilized with bismuth in brasses to supplant more harmful lead. The guideline of lead in drinking water applications, for example, in the US with the Safe Drinking Water Act of 1974, made a decrease of lead in metal important. The new metal is promoted under the name EnviroBrass. Like lead and sulfur, selenium works on the machinability of steel at focuses around 0.15%. Selenium creates a similar machinability improvement in copper amalgams.

4.9.5. Lithium-Selenium Batteries

The lithium-selenium (Li-Se) battery is perhaps the most encouraging frameworks for energy stockpiling in the group of lithium batteries. The Li-Se battery is an option in contrast to the lithium-sulfur battery, with a benefit of high electrical conductivity (Figure 4.13).

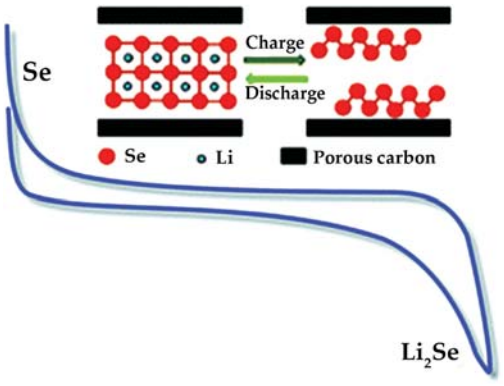

Figure 4.13. The rise of lithium-selenium batteries.

Source: https://pubs.rsc.org/en/content/articlelanding/2017/se/c6se00094k#!divAbstract.

4.10. SUN ORIENTED CELLS

Copper indium gallium selenide is a material utilized in sunlight-based cells. A copper indium gallium selenide sun-oriented cell (or CIGS cell, here, and there CI(G)S or CIS cell) is a flimsy film sun-based cell used to change over daylight into electric force. It is produced by storing a dainty layer of copper, indium, gallium, and selenium on glass or plastic sponsorship, alongside cathodes on the front and back to gather current. Since the material has a high assimilation coefficient and unequivocally retains daylight, a lot more slender film is needed than of other semiconductor materials.

CIGS is one of three standard dainty film photovoltaic (PV) advances, the other two being cadmium telluride and indistinct silicon. Like these materials, CIGS layers are sufficiently slender to be adaptable, permitting them to be stored on adaptable substrates. Notwithstanding, as these advances ordinarily utilize high-temperature testimony procedures, the best exhibition regularly comes from cells saved on glass, despite the fact that advances in low-temperature statement of CIGS cells have eradicated a lot of this presentation distinction. CIGS beats polysilicon at the cell level, be that as it may its module proficiency is still lower, because of a less develop upscaling.

Slight film portion of the overall industry is deteriorated at around 15%, leaving the remainder of the PV market to regular sunlight-based

cells made of glasslike silicon. In 2013, the piece of the pie of CIGS alone was around 2% and all slender film innovations joined fell under 10%. CIGS cells keep being created, as they guarantee to arrive at silicon-like efficiencies, while keeping up with their low expenses, as is ordinary for flimsy film technology. Prominent producers of CIGS PVs were the now-bankrupt organizations Nanosolar and Solyndra. Current market pioneer is the Japanese organization Solar Frontier, with Global Solar and GSHK Solar likewise delivering sunlight-based modules liberated from any hefty metals like cadmium and additionally lead. Numerous CIGS sun-oriented board producer organizations have failed.

4.11. PHOTOCONDUCTORS

Shapeless selenium (α-Se) slender movies have discovered application as photoconductors in level board x-beam indicators. These identifiers utilize shapeless selenium to catch and change over occurrence x-beam photons straightforwardly into electric charge (Figure 4.14).

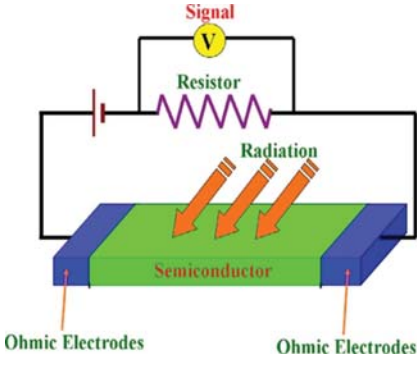

Figure 4.14. Schematics of photoconductors.

Source: https://www.researchgate.net/publication/51873152_ZnO-Based_Ultraviolet_Photodetectors/figures?lo=1&utm_source=google&utm_medium=organic.

Level board finders are a class of strong state x-beam advanced radiography gadgets comparable on a basic level to the picture sensors utilized in computerized photography and video. They are utilized in both projectional radiography and as an option in contrast to x-beam picture intensifiers (IIs) in fluoroscopy hardware.

4.12. RECTIFIERS

Selenium rectifiers were first utilized in 1933. Their utilization proceeded into the 1990s. A selenium rectifier is a kind of metal rectifier, imagined in 1933. They were utilized in power supplies for electronic gear and in high-current battery-charger applications until they were supplanted by silicon diode rectifiers in the last part of the 1960s. The appearance of the alternator in certain cars was the consequence of minimal, minimal expense, high-current silicon rectifiers. These units were sufficiently little to be inside the alternator case, not at all like the selenium units that went before silicon gadgets.

The amending properties of selenium, among different semiconductors, were seen by Braun, Schuster, and Siemens somewhere in the range of 1874 and 1883. The photoelectric and redressing properties of selenium were additionally seen by Adams and Day in 1876 and C. E. Fitts around 1886, yet pragmatic rectifier gadgets were not made regularly until the 1930s. Contrasted and the prior copper-oxide rectifier, the selenium cell could withstand higher voltage, yet at a lower current limit for each unit region (Kunhikrishnan et al., 2017).

4.13. DIFFERENT EMPLOYMENTS

Modest quantities of organoselenium compounds have been utilized to alter the impetuses utilized for the vulcanization for the creation of elastic.

Sulfur vulcanization is a synthetic cycle for changing over normal elastic or related polymers into materials of fluctuating hardness, flexibility, and mechanical sturdiness by warming them with sulfur or sulfur-based curatives or accelerators. Sulfur structures cross-connecting spans between segments of polymer chains which influences the mechanical and electronic properties. Many items are made with vulcanized elastic, including tires, shoe soles, hoses, and transport lines. The term vulcanization is gotten from Vulcan, the Roman divine force of fire.

The principle polymers exposed to sulfur vulcanization are polyisoprene (normal elastic, NR), polybutadiene elastic (BR) and styrene-butadiene elastic (SBR), which are all rich in unsaturated bonds. Several other strength rubbers may likewise be vulcanized, for example, nitrile elastic (NBR), butyl elastic (IIR) and EPDM elastic. Vulcanization, just the same as the relieving of other thermosetting polymers, is by and large irreversible. Be that as it may, huge endeavors have focused on creating ‘de-vulcanization’

measures for reusing of elastic waste. The interest for selenium by the gadgets business is declining Its PV and photoconductive properties are as yet helpful in copying, photocells, light meters, and sun powered cells. It is anything but a photoconductor in plain-paper copiers used to be a main application, however during the 1980s, the photoconductor application declined (in spite of the fact that it is anything but a huge end-use) as an ever-increasing number of copiers changed to natural photoconductors. However, once broadly utilized, selenium rectifiers have generally been supplanted (or are being supplanted) by silicon-based gadgets. The most remarkable exemption is in power DC flood security, where the predominant energy capacities of selenium silencers make them more alluring than metal-oxide varistors (MOVs).

A varistor is an electronic segment with an electrical opposition that differs with the applied voltage. Also known as a voltage-subordinate resistor (VDR), it has a nonlinear, non-ohmic flow voltage trademark that is like that of a diode. As opposed to a diode nonetheless, it has similar trademark for the two bearings of crossing current. Generally, varistors were to be sure developed by interfacing two rectifiers, for example, the copper-oxide or germanium-oxide rectifier in antiparallel setup. At low voltage the varistor has a high electrical opposition which diminishes as the voltage is raised. Current varistors are principally founded on sintered ceramic metal-oxide materials which show directional conduct just for a tiny scope. This sort is regularly known as the MOV.

Varistors are utilized as control or remuneration components in circuits either to give ideal working conditions or to secure against over-the-top transient voltages. When utilized as security gadgets, they shunt the current made by the extreme voltage away from touchy segments when set off.

The name varistor is a portmanteau of fluctuating resistor. The term is just utilized for non-ohmic differing resistors. Variable resistors, like the potentiometer and the rheostat, have ohmic qualities.

Zinc selenide was the primary material for blue LEDs; however, gallium nitride overwhelms that market. Cadmium selenide was a significant part in quantum dabs. Sheets of shapeless selenium convert X-beam pictures to examples of charge in xeroradiography and in strong state, level board X-beam cameras. Ionized selenium (Se+24) is one of the dynamic mediums utilized in X-beam lasers (Kaur et al., 2021).

Selenium is an impetus in some substance responses; however, it is anything but generally utilized due to issues with poisonousness. In X-beam

crystallography, joining of at least one selenium particles instead of sulfur assists with various frequency peculiar scattering and single frequency abnormal scattering staging.

Single-frequency bizarre diffraction (SAD) is a procedure utilized in X-beam crystallography that works with the assurance of the design of proteins or other organic macromolecules by permitting the arrangement of the stage issue. Rather than multi-frequency bizarre diffraction, SAD utilizations a solitary dataset at a solitary proper frequency. One benefit of the strategy is the minimization of time spent in the shaft by the gem, hence diminishing potential radiation harm to the atom while gathering information. Dismal is here and there called "single-frequency irregular scattering," however no dispersive contrasts are utilized in this procedure since the information are gathered at a solitary frequency. Today, selenium-SAD is regularly utilized for exploratory staging because of the improvement of strategies for selenomethionine joining into recombinant proteins.

Selenium is utilized in the conditioning of photographic prints, and it is sold as a toner by various photographic makers. Selenium escalates and broadens the apparent scope of high contrast photographic pictures and works on the changelessness of prints. 75Se is utilized as a gamma source in modern radiography.

4.14. CONTAMINATION

In high fixations, selenium goes about as a natural impurity. Wellsprings of contamination incorporate waste materials from certain mining, agrarian, petrochemical, and modern assembling activities. In Belews Lake North Carolina, 19 types of fish were wiped out from the lake due to 150–200 μg Se/L wastewater released from 1974 to 1986 from a Duke Energy coal-terminated force plant. At the Kesterson National Wildlife Refuge in California, a great many fish and waterbirds were harmed by selenium in horticultural water system waste.

Significant physiological changes may happen in fish with high tissue groupings of selenium. Fish influenced by selenium may encounter expanding of the gill lamellae, which obstructs oxygen dissemination across the gills and blood stream inside the gills. Respiratory limit is additionally decreased because of selenium restricting to hemoglobin. Different issues incorporate degeneration of liver tissue, growing around the heart, harmed egg follicles in ovaries, waterfalls, and gathering of liquid in the body pit and head. Selenium regularly causes a twisted fish hatchling which may have

issues taking care of or breathing; bending of the blades or spine is likewise normal. Grown-up fish may seem sound in spite of their powerlessness to create feasible posterity.

Selenium is bioaccumulated in oceanic environments, which brings about higher fixations in organic entities than the encompassing water. Organoselenium mixtures can be concentrated more than 200,000 times by zooplankton when water fixations are in the 0.5 to 0.8 μg Se/L reach. Inorganic selenium bioaccumulates more promptly in phytoplankton than zooplankton. Phytoplankton can think inorganic selenium by a factor of 3,000. Further fixation through bioaccumulation happens along the natural pecking order, as hunters devour selenium rich prey. It is suggested that a water convergence of 2 μg Se/L be considered exceptionally risky to touchy fish and oceanic birds. Selenium harming can be passed from guardians to posterity through the egg, and selenium harming may persevere for some ages. Multiplication of mallard ducks is debilitated at dietary centralizations of 7 ug Se/L. Numerous benthic spineless creatures can endure selenium focuses up to 300 μg/L of Se in their diet. (He et al., 2018).

Selenium contamination is affecting seas across the world and is essentially brought about by anthropogenic factors like cultivating overflow and modern processes. Fish are a significant wellspring of protein for people. Truth be told, 16.7% of the universes creature protein consumption came from fish in 2010. With fish as a wellspring of protein for people, know about the selenium contamination for its possible impact on people.

The high bioaccumulation of selenium in sea-going conditions causes enormous fish kills relying upon the species in the influenced area. There are, in any case, a couple of animal categories that have been believed to endure these occasions and endure the expanded selenium. It has likewise been proposed that season could affect the destructive impacts of selenium on fish. To assist with lessening the measure of selenium entering the seas, arrangements can be instituted, for example, utilizing organisms or chemicals that objective and separate metalloids like selenium.

4.15. BIOLOGICAL ROLE

Despite the fact that it is poisonous in enormous dosages, selenium is a fundamental micronutrient for creatures. In plants, it is anything but an onlooker mineral, once in a while in poisonous extents in scrounge (a few plants may aggregate selenium as a safeguard against being eaten by creatures, however different plants, like locoweed, require selenium, and

their development demonstrates the presence of selenium in soil).

Selenium is a part of the uncommon amino acids selenocysteine and selenomethionine. In people, selenium is a minor component supplement that capacities as cofactor for decrease of cancer prevention agent chemicals, for example, GPx, and certain types of thioredoxin reductase found in creatures and a few plants (this protein happens in every living being, yet not all types of it in plants require selenium).

The glutathione peroxidase group of catalysts (GSH-Px) catalyze certain responses that eliminate receptive oxygen species, for example, hydrogen peroxide and natural hydroperoxides:

$$2GSH + H_2O_2 – GSH\text{-}Px \rightarrow GSSG + 2H_2O$$

The thyroid organ and each cell that utilizes thyroid chemical use selenium, which is a cofactor for the three of the four known sorts of thyroid chemical deiodinases, which enact and afterward deactivate different thyroid chemicals and their metabolites; the iodothyronine deiodinases are the subfamily of deiodinase catalysts that utilization selenium as the generally uncommon amino corrosive selenocysteine. (Just the deiodinase iodotyrosine deiodinase, which chips away at the last breakdown results of thyroid chemical, does not utilize selenium.) (Cooper, 2021).

Selenium may repress Hashimoto's sickness, where the body's own thyroid cells are assaulted as unfamiliar. A decrease of 21% on TPO antibodies is accounted for with the dietary admission of 0.2 mg of selenium.

Expanded dietary selenium diminishes the impacts of mercury poisonousness, despite the fact that it is powerful just at low to unobtrusive dosages of mercury. Proof proposes that the sub-atomic instruments of mercury harmfulness incorporate the irreversible restraint of selenoenzymes that are needed to forestall and turn around oxidative harm in mind and endocrine tissues. A cell reinforcement, selenoneine, which is gotten from selenium and has been discovered to be available in the blood of bluefin fish, is the subject of logical exploration with respect to its potential parts in fiery and ongoing sicknesses, methylmercury detoxification, and oxidative harms. It appears like when mercury levels in a marine fish rise, so do the selenium levels. To the information on analysts, there are no reports of mercury levels surpassing that of selenium levels in sea fish.

4.16. DEVELOPMENT IN SCIENCE

From around 3 billion years prior, prokaryotic selenoprotein families drive the development of selenocysteine, an amino corrosive. Selenium is joined into a few prokaryotic selenoprotein families in microscopic organisms, archaea, and eukaryotes as selenocysteine, where selenoprotein peroxiredoxins ensure bacterial and eukaryotic cells against oxidative harm. Selenoprotein groups of GSH-Px and the deiodinases of eukaryotic cells appear to have a bacterial phylogenetic beginning. The selenocysteine-containing structure happens in species as different as green growth, diatoms, ocean imps, fish, and chickens. Selenium catalysts are associated with the little diminishing atoms glutathione and thioredoxin. One group of selenium-bearing atoms (the GPx) annihilates peroxide and fixes harmed peroxidized cell layers, utilizing glutathione. Another selenium-bearing chemical in certain plants and in creatures (thioredoxin reductase) produces decreased thioredoxin, a dithiol that fills in as an electron hotspot for peroxidases and furthermore the significant lessening catalyst ribonucleotide reductase that makes DNA antecedents from RNA forerunners (Figure 4.15) (Banuelos et al., 2002).

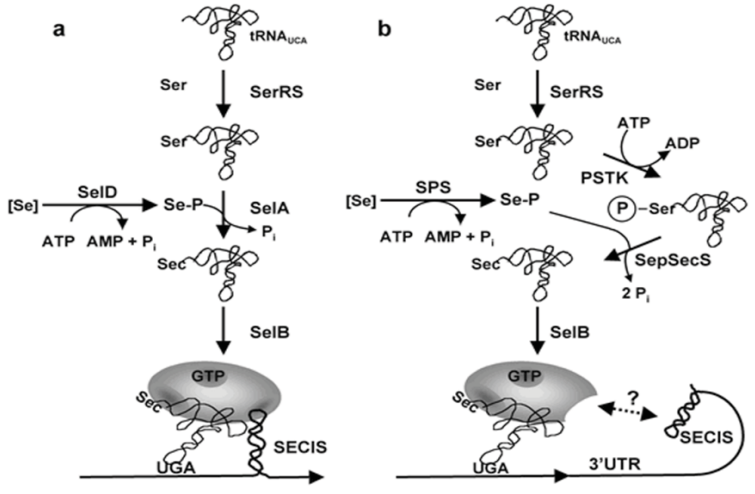

Figure 4.15. Prokaryotic selenoprotein biosynthesis and function.

Source: https://link.springer.com/chapter/10.1007/978-3-319-41283-2_5.

Minor components associated with GSH-Px and superoxide dismutase compounds exercises, for example selenium, vanadium, magnesium, copper, and zinc, may have been inadequate in some earthly mineral-insufficient regions. Marine organic entities held and here and there

extended their selenoproteomes, while the selenoproteomes of some earthbound organic entities were decreased or totally lost. These discoveries recommend that, except for vertebrates, sea-going life upholds selenium use, though earthbound environments lead to decreased utilization of this minor component. Marine fishes and vertebrate thyroid organs have the most elevated grouping of selenium and iodine. From around 500 million years prior, freshwater, and earthly plants gradually streamlined the creation of "new" endogenous cancer prevention agents, for example, ascorbic corrosive (nutrient C), polyphenols (counting flavonoids), tocopherols, and so on A couple of these showed up more as of late, in the last 50–200 million years, in foods grown from the ground of angiosperm plants. Indeed, the angiosperms (the predominant sort of plant today) and the vast majority of their cancer prevention agent shades advanced during the late Jurassic period (Hong et al., 2020).

The deiodinase isoenzymes establish another group of eukaryotic selenoproteins with distinguished catalyst work. Deiodinases can separate electrons from iodides, and iodides from iodothyronines. They are, subsequently, associated with thyroid-chemical guideline, taking part in the assurance of thyrocytes from harm by H_2O_2 created for thyroid-chemical biosynthesis. Around 200 million years prior, new selenoproteins were created as mammalian GSH-Px chemicals.

4.17. WHOLESOME WELLSPRINGS OF SELENIUM

Dietary selenium comes from meat, nuts, cereals, and mushrooms. Brazil nuts are the most extravagant dietary source (however this is soil-subordinate, since the Brazil nut does not need significant levels of the component for its own requirements).

The US recommended dietary allowance (RDA) of selenium for teens and grown-ups is 55 μg/day. Selenium as a dietary enhancement is accessible in numerous structures, including multi-nutrients/mineral enhancements, which ordinarily contain 55 or 70 μg/serving. Selenium-explicit enhancements commonly contain either 100 or 200 μg/serving (Hasanuzzaman et al., 2020).

In June 2015, the US Food and Drug Administration (FDA) distributed its last principle setting up the necessity of least and greatest degrees of selenium in newborn child equation. The selenium content in the human body is accepted to be in the 13–20 mg range.

4.17.1. Pointer Plant Species

Certain types of plants are viewed as markers of high selenium content of the dirt since they require undeniable degrees of selenium to flourish. The fundamental selenium pointer plants are Astragalus species (counting a few locoweeds), ruler's tuft (*Stanleya* sp.), woody asters (*Xylorhiza* sp.), and bogus golden weed (*Oonopsis* sp.).

4.17.2. Identification in Natural Liquids

Selenium might be estimated in blood, plasma, serum, or pee to screen extreme ecological or word related openness, to affirm a determination of harming in hospitalized casualties, or research an associated case with deadly excess. Some insightful strategies are equipped for recognizing natural from inorganic types of the component. Both natural and inorganic types of selenium are to a great extent changed over to monosaccharide forms (selenosugars) in the body before disposal in the pee. Disease patients getting day by day oral portions of selenothionine may accomplish high plasma and pee selenium fixations.

4.18. HARMFULNESS

In spite of the fact that selenium is a fundamental minor component, it is poisonous whenever taken in abundance. Surpassing the tolerable upper intake level (UL) of 400 micrograms each day can prompt selenosis. This 400 µg tolerable UL depends essentially on a 1986 investigation of five Chinese patients who showed clear indications of selenosis and a subsequent report on similar five individuals in 1992. The 1992 examination really tracked down the greatest safe dietary Se admission to be roughly 800 micrograms each day (15 micrograms for every kilogram body weight), yet proposed 400 micrograms each day to try not to make a lopsidedness of supplements in the eating regimen and to accord with information from other countries. In China, individuals who ingested corn filled in incredibly selenium-rich stony coal (carbonaceous shale) have experienced selenium harmfulness. This coal was displayed to have selenium content as high as 9.1%, the most elevated fixation in coal ever recorded (Tanmoy et al., 2019).

Signs and indications of selenosis remember a garlic scent for the breath, gastrointestinal issues, balding, sloughing of nails, weariness, peevishness, and neurological harm. Outrageous instances of selenosis can display cirrhosis of the liver, aspiratory edema, or death. Elemental

selenium and most metallic selenides have generally low poison levels on account of low bioavailability. Paradoxically, selenates, and selenites have an oxidant method of activity like that of arsenic trioxide and are poisonous. The persistent poisonous portion of selenite for people is around 2,400 to 3,000 micrograms of selenium for every day. Hydrogen selenide is a very harmful, destructive gas. Selenium likewise happens in natural mixtures, for example, dimethyl selenide, selenomethionine, selenocysteine, and methylselenocysteine, all of which have high bioavailability and are poisonous in enormous dosages.

On 19 April 2009, 21 polo horses passed on instantly before a match in the United States Polo Open. After three days, a drug store delivered an articulation clarifying that the ponies had gotten an inaccurate portion of one of the fixings utilized in a nutrient/mineral enhancement compound that had been mistakenly pre-arranged by an intensifying drug store. Investigation of blood levels of inorganic mixtures in the enhancement showed the selenium fixations were 10 to multiple times higher than ordinary in the blood tests, and 15 to multiple times higher than typical in the liver examples. Selenium was subsequently affirmed to be the harmful factor.

Selenium harming of water frameworks may result at whatever point new agrarian overflow flows through regularly dry, lacking grounds. This interaction filters regular solvent selenium compounds, (for example, selenates) into the water, which may then be gathered in new "wetlands" as the water vanishes. Selenium contamination of streams additionally happens when selenium is drained from coal vent debris, mining, and metal purifying, raw petroleum handling, and landfill. The resultant high selenium levels in streams were found to cause inborn problems in oviparous species, including wetland birds and fish. Elevated dietary methylmercury levels can enhance the mischief of selenium harmfulness in oviparous species (Okonji et al., 2020).

Connection between endurance of adolescent salmon and grouping of selenium in their tissues following 90 days (Chinook salmon) or 45 days (Atlantic salmon) openness to dietary selenium. The 10% lethality level (LC10 = 1.84 μg/g) was inferred by applying the biphasic model of Brain and Cousens to just the Chinook salmon information. The Chinook salmon information involve two series of dietary medicines, joined here on the grounds that the impacts on endurance are unclear.

In fish and other natural life, selenium is vital forever, yet harmful in high portions. For salmon, the ideal convergence of selenium is around 1

microgram selenium for each gram of entire body weight. Much underneath that level, youthful salmon kick the bucket from deficiency; much above, they pass on from harmful excess.

The Occupational Safety and Health Administration (OSHA) has drawn the legitimate line (reasonable openness limit) for selenium in the work environment at 0.2 mg/m^3 over an 8-hour workday. The National Institute for Occupational Safety and Health (NIOSH) has drawn a recommended openness line (REL) of 0.2 mg/m^3 over an 8-hour workday. At levels of 1 mg/m^3, selenium is quickly risky to life and health.

4.19. INSUFFICIENCY

Selenium inadequacy can happen in patients with seriously compromised intestinal capacity, those going through absolute parenteral sustenance, and in those of old age (more than 90). Likewise, individuals reliant upon food developed from selenium-lacking soil are in danger. Albeit New Zealand soil has low degrees of selenium, negative health impacts have not been identified in the residents (Thomson, 2004; https://pubmed.ncbi.nlm.nih.gov/15137917/).

Selenium inadequacy, characterized by low (<60% of ordinary) selenoenzyme movement levels in cerebrum and endocrine tissues, happens just when a low selenium level is connected with an extra pressure, for example, high openings to mercury or expanded oxidant stress from nutrient E deficiency.

Selenium connects with different supplements, like iodine and nutrient E. The impact of selenium insufficiency on wellbeing stays dubious, especially according to Kashin-Beck disease (KBD). Also, selenium connects with different minerals, like zinc and copper. High dosages of Se supplements in pregnant creatures may upset the Zn:Cu proportion and lead to Zn decrease; in such treatment cases, Zn levels ought to be observed. Further investigations are expected to affirm these interactions (Garousi et al., 2016).

In the locales (for example different areas inside North America) where low selenium soil levels lead to low fixations in the plants, some creature species might be lacking except if selenium is enhanced with diet or injection. Ruminants are especially vulnerable. As a general rule, ingestion of dietary selenium is lower in ruminants than different creatures, and is lower from rummages than from grain. Ruminants brushing certain scrounges, e.g.,

some white clover assortments containing cyanogenic glycosides, may have higher selenium requirements, probably on the grounds that cyanide is delivered from the aglycone by glucosidase movement in the rumen and GPx is deactivated by the cyanide following up on the glutathione moiety. Neonate ruminants in danger of white muscle infection might be controlled both selenium and nutrient E by infusion; a portion of the WMD myopathies react just to selenium, some just to nutrient E, and some to by the same token.

4.20. HEALTH EFFECTS

It has been proposed that selenium supplementation may assist with forestalling malignancy rate in individuals, yet research has set up there is no proof to help such cases.

Selenium exists in two structures: inorganic (selenate and selenite) and natural (selenomethionine and selenocysteine). The two structures can be acceptable dietary wellsprings of selenium. Soils contain inorganic selenites and selenates that plants amass and convert to natural structures, generally selenocysteine and selenomethionine and their methylated subsidiaries.

Most selenium is as selenomethionine in creature and human tissues, where it tends to be consolidated vaguely with the amino corrosive methionine in body proteins. Skeletal muscle is the significant site of selenium stockpiling, representing around 28% to 46% of the complete selenium pool. Both selenocysteine and selenite are diminished to produce hydrogen selenide, which thusly is changed over to selenophosphate for selenoprotein biosynthesis.

The most regularly utilized proportions of selenium status are plasma and serum selenium fixations. Focuses in blood and pee reflect late selenium consumption. Investigations of hair or nail selenium content can be utilized to screen longer-term admissions over months or a long time. Evaluation of at least one selenoproteins, (for example, GPx, and selenoprotein P) is likewise utilized as a utilitarian proportion of selenium status. Plasma or serum selenium convergences of 8 micrograms (mcg)/dL or higher in solid individuals ordinarily address issues for selenoprotein blend.

4.21. SUGGESTED INTAKES

Admission suggestions for selenium and different supplements are given in the dietary reference intakes (DRIs) created by the Food and Nutrition

Board (FNB) at the Institute of Medicine of the National Academies (once in the past National Academy of Sciences). DRI is the overall term for a bunch of reference esteems utilized for arranging and evaluating supplement admissions of solid individuals. These qualities, which differ by age and sex, include:

- ***Suggested Dietary Allowance (RDA):*** Average every day level of admission adequate to meet the supplement prerequisites of practically all (97%–98%) sound people; regularly used to design healthfully sufficient eating regimens for people.
- **Sufficient Intake (AI):** Intake at this level is accepted to guarantee dietary ampleness; set up when proof is inadequate to foster an RDA.
- ***Assessed Average Requirement (EAR):*** Average day by day level of admission assessed to meet the prerequisites of half of solid people; typically used to evaluate the supplement admissions of gatherings of individuals and to design healthfully sufficient weight control plans for them; can likewise be utilized to survey the supplement admissions of people (Frankenberger et al., 2004).
- ***Decent Upper Intake Level (UL):*** Maximum day by day admission improbable to cause unfavorable wellbeing impacts.

4.22. WELLSPRINGS OF SELENIUM FOOD

Brazil nuts, shellfishes, and organ meats are the most extravagant food wellsprings of selenium. Different sources incorporate muscle meats, cereals, and different grains, and dairy items. The measure of selenium in drinking water is not healthfully critical in most geographic districts. The significant food wellsprings of selenium in the American eating regimen are breads, grains, meat, poultry, fish, and eggs.

The measure of selenium in a given kind of plant-put together food depends with respect to the measure of selenium in the dirt and a few different elements, for example, soil pH, measure of natural matter in the dirt, and regardless of whether the selenium is in a structure that is agreeable to plant take-up. Therefore, selenium focuses in plant-based food varieties fluctuate broadly by geographic area. For instance, as per the U.S. Division of Agriculture Food Composition Database, Brazil nuts have 544 mcg selenium/ounce, yet values from different examinations change broadly. The selenium content of soil influences the measures of selenium in the

plants that creatures eat, so the amounts of selenium in creature items additionally fluctuate. Notwithstanding, selenium fixation in soil smallerly affects selenium levels in creature items than in plant-based food sources since creatures keep up with unsurprising tissue centralizations of selenium through homeostatic components. Moreover, detailed domesticated animals take care of for the most part contain similar degrees of selenium. The U.S. FDA created DVs (daily values) to help purchasers think about the supplement substance of food varieties and dietary enhancements inside the setting of an absolute eating routine. The DV for selenium is 55 mcg for grown-ups and youngsters matured 4 years and more seasoned. FDA does not need food names to list selenium content except if selenium has been added to the food. Food sources giving 20% or a greater amount of the DV are viewed as high wellsprings of a supplement, however food sources giving lower rates of the DV additionally add to an energizing eating routine (Feng et al., 2021). The U.S. Department of Agriculture (USDA) records the nutrient content of various food sources and gives a far-reaching rundown of food sources containing selenium determined by supplement content and by food name.

4.23. DIETARY SUPPLEMENTS

Selenium is accessible in multivitamin/multimineral supplements and as an independent enhancement, frequently in the types of selenomethionine or of selenium-improved yeast (filled in a high-selenium medium) or as sodium selenite or sodium selenate. The human body assimilates over 90% of selenomethionine however just about half of selenium from selenite (Figure 4.16).

Figure 4.16. Selenium 100 mcg tablets.

Source: https://westerncosmetics.com/shop/selenium-100-mcg-tablets/.

Not many examinations have thought about the general retention and bioavailability of various types of selenium. In one examination, 10 gatherings of selenium-packed subjects were arbitrarily allocated to get a fake treatment or either 200 or 600 mcg/day selenium as selenomethionine, sodium selenite, or high-selenium yeast (in which an expected 75% of selenium was as selenomethionine) for about four months. Selenium bioavailability, in light of urinary discharge, was most prominent for selenomethionine and least for selenite. Notwithstanding, supplementation with any of these structures just influenced plasma selenium levels and not GPx action or selenoprotein P fixation, affirming that review members were selenium packed before they started taking selenium supplements.

4.24. SELENIUM INTAKES AND STATUS

Most Americans burn-through sufficient measures of selenium. As indicated by an investigation of information from the 2009–2010 National Health and Nutrition Examination Survey (NHANES), the normal every day selenium admission in Americans matured 2 years and more established from food varieties is 108.5 mcg and from the two food sources and enhancements is 120.8 mcg. Grown-up men have higher day by day admissions (134 mcg from food varieties and 151 mcg from food sources and enhancements) than grown-up ladies (93 mcg from food sources and 108 mcg from food varieties and enhancements). In the United States, 18% to 19% of grown-ups and youngsters utilize a dietary enhancement that have selenium (Bailey, 2017).

As per an examination of NHANES information from 2003–2004, the average serum selenium fixation in U.S. grown-ups matured 40 years or more seasoned is 13.67 mcg/dL. Men have marginally higher serum selenium levels than ladies, and whites have more elevated levels than African Americans.

Selenium admissions and serum focuses in the United States and Canada change to some degree by area in view of contrasts in the measures of selenium in soil and in neighborhood food sources burned-through. For instance, focuses are higher in inhabitants of the Midwestern and Western United States than in the South and Northeast. The broad vehicle of food ordinarily permits individuals living in low-selenium regions to acquire adequate measures of selenium.

4.25. SELENIUM DEFICIENCY

Selenium insufficiency produces biochemical changes that may incline individuals who experience extra anxieties to foster certain sicknesses. For instance, selenium insufficiency in blend with a subsequent pressure (perhaps a viral contamination) prompts Keshan illness, a cardiomyopathy that happened in pieces of China before an administration supported selenium supplementation program that started during the 1970s. Before the Chinese government supplementation program, adults in the Keshan contaminated regions had average selenium admissions of close to 11 mcg/day; admissions of no less than 20 mcg/day can protect adults from Keshan disease (KD).

Selenium insufficiency is likewise connected with male fruitlessness and might assume a part in Kashin-Beck sickness, a sort of osteoarthritis that happens in certain low-selenium spaces of China, Tibet, and Siberia. Selenium inadequacy could intensify iodine insufficiency, conceivably expanding the danger of cretinism in newborn children.

CHAPTER 5

SELENIUM HEALTH BENEFITS BASED ON SCIENCE

CONTENTS

5.1. INTRODUCTION

Selenium is a component of the group of micronutrients that are essential for the appropriate performance of the organisms in trace amounts. Selenium participates in the control and protection of immunologic and reproductive systems in the treatment of cells against excess H_2O_2. heavy metal detoxifications. It also ensures that the thyroid gland works properly. Selenium induces the appearance of the process of selenium protein production involved in the individual's antioxidant defense mechanism. The study of selenium has been phenomenally successful in recent years. Selenium has been shown to have anti-carcinogenic capabilities against a variety of malignancies. Supplementation becomes a solution to this problem more and more. A wide variety of additional techniques promote studies in this field. Light differences in selenium can lead to excess or deficiency, so additional measures need to be carried out with care and prudence (Figure 5.1).

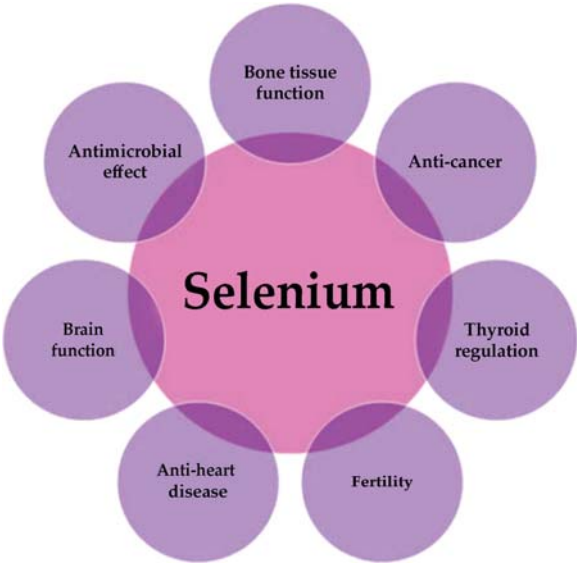

Figure 5.1. Even if you have never known of selenium, it is an essential component for your wellbeing. Selenium is an important mineral, which means you must get it through your diet. It is only required in trace amounts, yet it is critical for vital bodily functions like metabolism and thyroid function.

Source: https://www.researchgate.net/figure/The-health-benefits-of-selenium_fig2_324800200.

Berzelius, a Swedish scientist, discovered selenium in 1817, which sparked research into the effects of inorganic substances of the element on living creatures. Schwartz and Folz unexpectedly revealed selenium's protective impact on organisms in 1957. As a result of these investigations, selenium was included to a list of trace elements whose deficiency in the diet can lead to a variety of disorders. Because of its biological activity and significance in animal and human nutrition, selenium has a positive influence on wellbeing and the immune system (El-Ramady et al., 2020).

Selenium insufficiency in the diet can be harmful to one's health. Dietary selenium shortage affects 0.5–1 billion individuals worldwide, and many countries are currently deficient in this nutrient. The maximum daily consumption of selenium, as per the World Health Organization (WHO), should not surpass 70 g. It is important to stick to the prescribed supply dosage as well as the element's upper tolerated consumption limit. Selenium dosages of more than 400 g/day to 700 g/day may be hazardous. The typical amount of selenium in a person's daily diet is much below the necessary amount. The typical amount of selenium in a person's daily diet is much below the necessary amount. In several European nations, the estimated content based on typical household consumption is between 30 and 50 g/day.

Given the wide range of selenium intakes, intensive educational initiatives on the good effects of this element on health should be implemented. Its hazardous effects, nevertheless, should not be overlooked, especially given its limited therapeutic index, as its toxic dose begins at 400 g/day. It should be mentioned that unchecked consumption of selenium-enriched items might lead to toxicity. Human hair loss, diarrhea, and emesis have been linked to the ingestion of the fruit of the species Lecythis ollaria, which accumulates large levels of selenium. Foods containing selenium have a wide range of selenium content. It is determined by the amount of selenium in the soil in each location, as well as the ability of plants to acquire this element. Other elements, including as meteorological circumstances, farming, and breeding procedures, and food preparation processes, all have an impact (Figure 5.2).

Figure 5.2. The numerous excellent health advantages of this great antioxidant and vital trace mineral have been carefully investigated. Selenium is required for the development of enzymes known as selenoproteins, which are essential for DNA synthesis, thyroid hormonal balance, immune response support, and oxidative stress protection.

Source: https://mbbch.com/nutrition/health-benefits-of-selenium-evidence-based-research/.

Selenium is most found in dietary products in association with proteins, hence products with a high protein content usually have a greater selenium concentration. Meat, seafood, offal, and cereals are among these items. The selenium level of beef products varies between 0.08 and 0.73 g/g. Selenium is abundant in both marine (0.110.97% g/g) and freshwater (0.180.68% g/g) fish. Selenium concentrations in cereals range from 0.01 to 0.55 g/g. Selenium levels in dairy products are inversely proportional to fat content, ranging from 0.01 to 0.55 g/g. Selenium is found in modest amounts in fruits and vegetables, ranging from 0.001 to 0.022 g/g. This is due to their low protein content and high-water content. Despite this, Brazil nuts and mushrooms contain extremely high quantities of this element. Mushrooms have a high proportion of protein in their dry matter, ranging from 16.5% to 39%, hence their protein fractions include significant quantities of organic selenium. In selenium speciation studies, common mushrooms (*Agaricus bisporus*) are among the most examined mushrooms. In Europe and the United States, they are considered a delicacy. In most plants, considerable levels of selenium cannot be accumulated (selenium content rarely reaches

100 g/g). Plants of the Brassica genus have also been shown to contain high levels of selenium (kohlrabi, cauliflower, cabbage, and broccoli (Déon et al., 2017).

Onions and garlic are high in selenium, which helps to reduce the risk of cancer. Furthermore, eating these plants does not result in an excessive buildup of selenium in tissues or any other problems. The most frequent type of selenium in their composition is Se-methyl selenocysteine and y-glutamyl-Se-methyl selenocysteine. Preparations that are high in macronutrients and trace elements are especially important. Vitamin and mineral supplements, as well as supplements containing other critical components, fall into this category. Selenium can be found in these preparations as inorganic combinations (typically Se (IV)) or organic compounds (selenoamino acids). It should be noted that yeast formulations are a great source of selenium. Selenium yeasts are a valuable source of easy-to-assimilate selenium compared with preparations containing inorganic selenium.

Selenium is a trace element that is required for life, as demonstrated by its cumulative function with vitamin E in 1979. Selenium insufficiency is becoming more common in different regions of the world, resulting in a variety of clinical conditions. Patients with phenylketonuria or those suffering from diet-related disorders are particularly prone to the negative consequences of selenium deficiency. Individuals who have been exposed to specialized chemotherapy or who have already received radiotherapy are also at risk of having lower levels of this micro-element in their bodies.

Selenium deficiency has been demonstrated in animals and humans living in areas with low selenium levels in the soil. In a vast area of China, as well as Central and Eastern Siberia, the most catastrophic consequences of selenium shortage have been observed. It is primarily caused by a lack of this micronutrient in the diet, differing social groups' culinary preferences, or changes in eating habits. Selenium shortage causes organ and tissue deterioration, as well as changes in the biological processes in which it participates, due to decreased expression of selenoproteins. The most common symptoms of selenium deficiency in people and animals are cardiac muscle and joint issues. Moderate deficiency in this vitamin can have detrimental consequences for human health, such as increasing the risk of infertility in men, prostate cancer, nephropathy, and the emergence of neurological illnesses. Selenium deficiency also leads to dilated cardiomyopathy (Keshan disease (KD)) and endemic osteoarthritis (Kashin-Beck disease (KBD)) (Figure 5.3).

Figure 5.3. Although selenium is necessary for good health, too much can lead to selenium toxicity, or selenosis. We should not consume more than 300 mcg per day, according to the European Food Safety Authority. Each Brazil nut contains approximately 70–90 micrograms of selenium; eating four nuts at once on a regular basis may indicate that you are consuming too much selenium.

Source: https://explore.globalhealing.com/7-ways-selenium-benefits-your-body/amp/.

Rheumatoid arthritis, shortening toes and fingers, and growth problems are all symptoms of Kashin-Beck illness. Degeneration (necrosis) of hyaline cartilage occurs when oxidative damage to cartilage causes deformation of the bone structure. This condition primarily affects youngsters between the ages of 5 and 13. The combination of selenium and iodine insufficiency is a factor that promotes Kashin-Beck illness development. Keshan is another disease linked to a selenium deficit. It is a type of juvenile cardiomyopathy that affects mostly young women of reproductive age and children aged 2 to 10. Selenium insufficiency can lead to the development of additional disorders, such as asthma, which is linked to impaired glutathione peroxidase (GPx) activity, AIDS, which is accelerated by selenium deficiency, poor circulation, myocardial infarction, strokes, or sudden infant death syndrome. The importance of selenium supplementation cannot be overstated. The utilization of selenium enriched yeasts as fodder components, plant enhancement as well as added Selenate straightforwardly to the fodder or oral administering of sodium selenite should also be distinguished from the

methodologies of addition. The benefits of Selenium are discussed below (Charya, 2017).

5.2. AS AN ANTIOXIDANT

The significance of oxygen-free electrons, also known as "reactive oxygen species" (ROS) and "reactive nitrogen species" (RNS), in clinical and experimental medicine has been extensively researched in recent years. The action of non-enzymatic antioxidants, as well as antioxidant enzymes, counteracts the effects of reactive oxygen and nitrogen species. Natural flavonoids, thiols, carotenoids, Vitamin E, Vitamin C, and other chemicals are the most effective non-enzymatic antioxidants, whereas antioxidant enzymes including GPx, catalase, and superoxide dismutase, catalase.

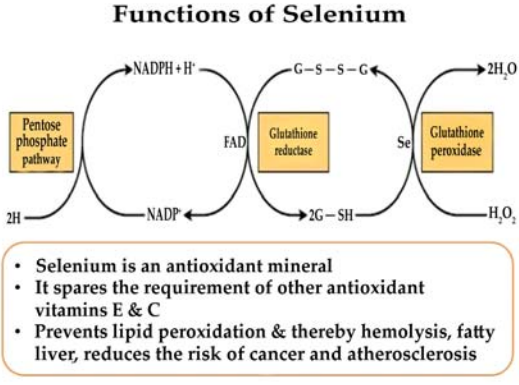

Figure 5.4. Concurrent deficit of copper or manganese enhances the potentiating effect of Se deficiency on lipid peroxidation in particular tissues. The molecular form of Se is a key element in inducing cellular responses in the in vitro system. Although the lethal processes of selenite and other redoxing Se compounds are unknown, it is thought that they arise from their ability to catalyze the oxidation of thiols while also producing superoxide.

Source: https://www.slideshare.net/NiranjanGopal/zinc-and-slenium.

Nutritional variables, such as some trace nutrients, may influence the natural functioning of antioxidant enzymes. Minerals such as copper, manganese, zinc, selenium, and iron have been shown to be significant cofactors in the control of antioxidant enzyme activity. GPx is an enzyme antioxidant that comes in two varieties: one that is selenium-independent and another that is selenium-dependent. The features of both GPx allow

them to rule out peroxidase as potential Fenton reaction substrates (Figure 5.4).

Because of these factors, as well as the thin line between toxicity and necessity for Se, this element has attracted a lot of attention as an important nutrient. Selenoproteins may be the mechanism via which selenium has favorable impacts on health. Selenoenzymes like GPx (which reduces peroxides), iodothyronine deiodinases (which regulate thyroid hormone activity), and thioredoxin reductases are all made up of the amino acid selenocysteine (regenerating antioxidant systems). Many of the roles of a rising number of selenoproteins are unknown in comparison to these well-studied enzymes.

In addition, selenium substitutes sulfur in methionine to generate selenomethionine, which can be absorbed into proteins non-specifically. Se-containing low-molecular-weight compounds have also been shown to have antioxidant and anticancer properties (both natural and synthesized). As a result, low or inadequate selenium intake has been linked to a wide range of human disorders, including heart disease, cystic fibrosis, and numerous types of cancer. The investigation of selenium compounds as a relevant group of cancer chemo-preventive medicines was carried out by Clark and co-workers.

Certain selenium organic forms have been linked to anti-carcinogenic action, and because selenium can only be received from food, it is critical to know selenium dietary sources. The National Research Council determined a selenium recommended dietary allowance (RDA) for humans, which is 55 and 70 grams per day for men and women, respectively. Most of the selenium is obtained from grains, seafood, meat, and dairy products. Supplementing with selenium has also been recommended to boost daily selenium consumption; however, recent investigations have revealed that the amount of selenium in over-the-counter pills can be substantially lower than stated (Figure 5.5) (Domokos-Szabolcsy et al., 2018).

As a result, boosting selenium consumption through natural sources appears to be a priority. The amount of selenium in plants varies greatly depending on the amount of selenium in the soil, which is related to the geographic zone. Many selenium-deficient locations exist around the world, primarily in Australia and Asia.

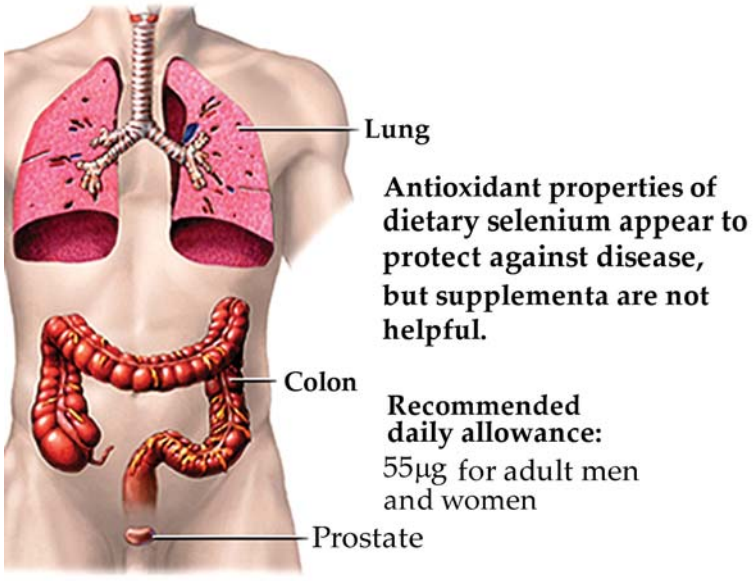

Figure 5.5. Antioxidants including selenium help to minimize oxidative stress by lowering the quantity of free radicals in the body. They defend cells from injury induced by oxidative stress by scavenging excess free radicals. Selenium is an antioxidant that fights oxidative stress and aids in the prevention of chronic diseases including cancer and heart disease.

Source: https://medlineplus.gov/ency/imagepages/19304.htm.

Since the uptake, tissue allocation, and body utilization of selenium are all dependent on the organic compounds of the component present in food, the dietary supplementation of selenium is determined by its concentration in food, the quantity of nutrients consumed, the chemical form of the component, and its bioavailability. As a result, it is critical to establish the selenium concentration of several regularly consumed meals to estimate daily selenium consumption in each region, as well as the most common selenium species. Selenium speciation has been a popular issue in natural product analytical chemistry, with most investigations focusing on Allium plants, selenized yeast, and cooked and fresh fish and poultry.

For instance, most of the selenium in Se-yeast and Se-garlic is in the form of selenomethionine (85%) and y-glutamyl-Se-methilselenocysteine (73%), respectively, and Se garlic was substantially more efficient in trying to suppress the advancement of malignant tumors and the emergence of

adenocarcinomas in the mammary gland of Carcinelli mice. As a result, researchers are looking at the effects of various species and their health implications. Some plants have a high selenium sensitivity and can convert inorganic forms into Se amino acids. If vegetables with a high sulfur content are grown in this fertilized medium, selenium concentration should be expected. Garlic, which is high in a variety of sulfur compounds, was used to test this theory. Selenium analogs of many of these sulfur-containing compounds are generated when garlic is grown in a selenium-fertilized media. Because of its sulfate-like properties, selenate is quickly absorbed and distributed by plants. Selenite, on the other hand, is converted into seleno-amino acids more quickly (Bini, 2009). The substitution of Se-analogous amino acids for methionine and cysteine results in a change in protein structure that affects plant activities. As a result, the tolerance mechanism has been postulated to be the production of non-protein seleno-amino acids in plants, such as selenomethylselenocysteine and y-gluthamil-selenomthyl-selenocysteine. To gain a better understanding of Se's significance, researchers should examine selenium accumulation and transformation in the reproductive stage of various vegetables, as well as selenium species and amounts in the edible section after cooking (Figure 5.6).

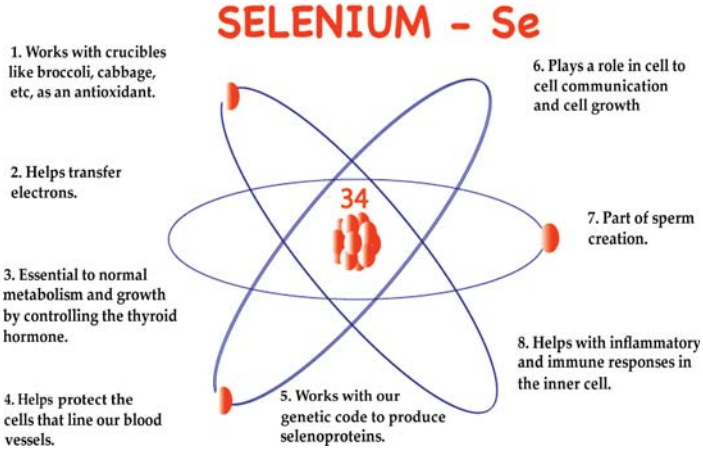

Figure 5.6. Although selenium insufficiency is uncommon in humans, it can arise if a patient's intestines are badly weakened or if the intravenous fluid, they are receiving lacks selenium. People over the age of 90 have a hard time getting selenium into their bodies. Muscle weakening, muscle atrophy, and cardiac muscle issues occur over time in these persons.

Source: https://www.mindbodyandfood.ca/about-minerals/selenium/.

Meat and fish tend to contribute a consistent amount of Se to the diet, ranging from 40% to 50% of total Se consumption. Because of two factors: their large consumption and the capacity of some animals to accumulate Se, assessments of total selenium and associated species in meat and fish samples are of interest. The enzyme GPx, on the other hand, is one of the most significant selenoproteins. By accelerating the reduction of lipid and hydrogen peroxides, GPx aids in the oxidative defense of animal tissues.

Meat's oxidative stability is determined by the ratio of antioxidants to prooxidants, as well as the presence of oxidation intermediates such as polyunsaturated fatty acids (PUFA), triglycerides, protein, and pigments. As a result, various authors have investigated the distribution of selenium and GPx in bovine and porcine organs to better understand the role of these chemicals in food stability and to assess the suitability of selenium-rich organs for human consumption. Aside from endogenous enzymes, the presence of dietary antioxidants determines the oxidative stability of meat (for example, Vitamin E's significance in preventing lipid oxidation is well understood).

Despite the rising number of studies on the subject, the impact of other dietary molecules with anti-oxidative capabilities, such as carotenoids or flavonoids, and the involvement of endogenous enzymes on the oxidative status of meat are not well understood. Meat products are a major source of elements like selenium, zinc, iron, and copper. The bioavailability of these components is influenced by a variety of dietary variables. Bioavailability of Fe, Zn, and Cu in meat products is typically high. Both natural and inorganic forms of selenium are swiftly absorbed, however selenomethionine, the most common form of dietary selenium, is more easily absorbed than inorganic forms. Moreover, nutrient interactions among elements can influence Se's bioavailability during uptake. Other elements related to the antioxidant system, such as Zn via superoxide dismutase, Cu by cytosolic Cu, while Fe showed a role in accelerating lipid oxidation, which is why the effects of the other factors and their contributions to animal feeds are important to be understood (Figure 5.7).

Figure 5.7. The most common form of selenium found in animal tissue is selenomethionine, which is largely deposited in skeletal muscle. It is estimated, indeed, that the skeletal muscle stores between 28% and 46% of the selenium of the body. Seafood and meat of organ are known as food products containing the highest selenium concentrations, while muscular meat, cereal, and milk products are other good sources.

Source: https://www.news-medical.net/amp/health/Sources-of-Selenium.aspx.

Furthermore, animals fed Se and tocopherol deficient diets have been found to be the most susceptible to oxidation. Furthermore, it has been demonstrated that high-Se diets restore GPx activity; however, supplementation with tocopherol is preferable in poultry farming since it is related with decreased meat drip loss, a bigger rise in meat Se content, and superior productive qualities. As a result, a reliable and accurate quantification of these elements in animal diets and meat products is another research area that allows researchers to investigate the effects of these dietary factors.

Vitamin and mineral fortification of specific foods, like cereal, dairy, and flour, is now being extended to other goods. Antioxidants, phytochemicals like carotenoids and flavonoids, and other nutrients are included in fortification. Snack bars fortified with various vitamins and minerals; juices supplemented with vitamins C, E, and calcium; drinks fortified with carotenoids, vitamins, and minerals; margarines fortified with-carotene and sterols, and so on are examples of such items. Foods are frequently supplemented with antioxidant vitamins and other antioxidants. Fortification, of course, supplies both antioxidants and prooxidants (Badr et al., 2020).

In the case of selenium fortification, it has been shown that Se and vitamin E (tocopherol) are linked in the *in vivo* antioxidant system in two ways: first, the creation of GPx aids in the decomposition of lipid hydroperoxides into non-pro-oxidant organisms; and second, tocopherol operates as a chain-breaking antioxidant. Other ongoing study areas must include determining the bioavailability of various selenium compounds as well as their change throughout the food processing.

5.3. IN CARDIOVASCULAR DISEASES (CVDS)

Early reports of a quickly developing and severe cardiomyopathy (KD), which is distinguished by cardiac necrosis and calcification, provided the first clues about the importance of selenium in the cardiovascular system. Even though selenium deficiency appears to be the key pathogenic component in the development and occurrence of this disease, it was later thought to be more of a conditioned predisposing factor than an etiologic factor for this type of juvenile cardiomyopathy (Figure 5.8).

Figure 5.8. In observational studies, selenium levels were found to be inversely related to the risk of coronary heart disease. The validity of this link is disputed because observational studies have generated misleading data for various antioxidants. The cardiovascular efficacy of selenium supplementation has only been studied in a few randomized trials, and the results are still unclear.

Source: https://nutritionreview.org/2017/09/selenium-and-coq10-combo-cuts-heart-disease-deaths-in-half/.

Previous research has shown that supplementing deficient animals with selenium decreased the cardiotoxicity of the coxsackie B virus, which was previously identified from patients with KD. Following research supported these findings, showing that mice fed a selenium-deficient diet were more susceptible to developing viral-induced cardiomyopathy. Although the specific processes are unknown, recent investigations have proven the protective qualities of GPx activity on illness progression and indicated greater sensitivity to this viral infection in mice with 50% of GPx1 deletion, but wild-type animals were resistant.

5.3.1. Selenoproteins and Selenium in Myocardial Infarcts

In general, the GPx family of selenoproteins is one of the best-studied in the field of cardiovascular biology. Experiments looking into the role of selenium shortage in the development of non-infectious cardiovascular disorders have found that the link between low selenium consumption and cardiovascular disorders could be due to increased oxidative stress and its consequences. Animal experiments employing various selenium dosages and formulae, as well as investigations in GPx knockout mice, have highlighted selenium's critical role in neutralizing reactive oxygen and nitrogen species, hence minimizing organ harm following cardiac ischemia/reperfusion. Aside from the GPx isoforms, thioredoxin reductase is hypothesized to regulate the cardiovascular system by oxidizing intracellular and extracellular signaling molecules, which has an impact on adaptive responses like remodeling (Wang et al., 2018).

Other selenoproteins' impact on the cardiovascular system and disease progression is only partially known. Lu and colleagues were the first to show that selenoprotein K has a role in cardiomyocyte antioxidant defense mechanisms. Venardos and colleagues showed in a rat model that selenium deprivation causes enhanced myocardial damage with increased protein and lipid peroxidation during myocardial I/R.

These findings were backed up by Tanguy and co-workers' tests, which revealed that a selenium shortage in rats resulted in higher myocardial injury and a delayed recovery of heart function following myocardial I/R. The decrease in GPx activity recorded in the blood and cardiomyocytes was the cause of this discovery. Following these findings, other experimental research attempted to reduce known myocardial I/R injury by supplementing with selenium through a selenium-rich diet. In fact, when rats on a low selenium

diet were compared to those fed a high selenium diet, the Venardos group showed much less myocardial I/R injury.

Tanguy and coworkers further validated selenium's therapeutic benefits, showing enhanced cardiac tissue regeneration, considerably decreased myocardial damage, and a lower incidence of post-ischemic cardiac arrhythmia in rats given the maximum selenium dose. The fundamental causes of these findings are only partially understood. Since I/R-related oxidative stress is known to have a role in altered recovery, enlarged infarction size, and the etiology of post-ischemic arrhythmias, selenium is thought to contribute its protective effects primarily as an important co-factor of numerous antioxidants. However, further research is necessary at the molecular scale to better understand the selenium-dependent impacts.

Selenium is required for the selenoprotein-induced defense system to function properly. As a result, selenium blood levels have become a popular biomarker for oxidative stress-related illnesses. The impact of serum selenium levels on the development of cardiovascular illnesses has been studied in several observational studies.

5.3.2. As a Biomarker

Oxidative stress is important in both the chronic and acute phases of coronary heart disease (CHD). The function of GPx and other antioxidant selenoproteins, that are necessary for redox homeostasis and adequate antioxidant defense, is recognized to be favorably associated with selenium levels in the blood. Reduced selenium levels may consequently result in insufficient protection against LDL oxidation (the primary cause of atherosclerotic plaque formation) through uptake by endothelial cells and macrophages in the chronic development of CHD.

Because proper selenium levels are dependent on daily caloric intake, it was discovered that cardiovascular disease (CVD) is linked to low selenium levels, resulting in poor GPx activity. Flores-Mateo et al. found an inverse relationship between selenium concentrations and the risk of CHD in a meta-analysis published in 2006. The validity of the observational studies examined, however, was questioned. Another meta-analysis of 13 prospective cohort studies discovered a moderate negative link between serum/plasma selenium and CHD but cautioned that the results were difficult to interpret due to potential protocol biases (Figure 5.9) (Ali et al., 2021).

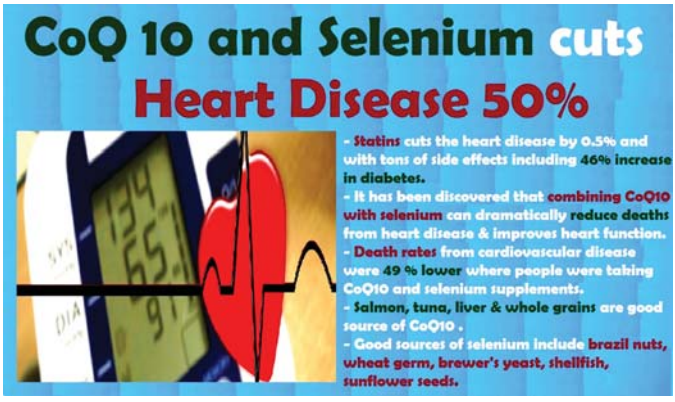

Figure 5.9. Researchers discovered that CoQ10 and selenium are still helpful at reducing cardiovascular mortality, even though the trial began 10 years ago. The protective effect persisted even after the trial individuals stopped taking the supplements. The initial supplement group had a 49% lower death rate from cardiovascular illness, including heart attacks, strokes, and congestive heart failure, with both men and women receiving equal protection.

Source: https://www.linkedin.com/pulse/coq-10-selenium-cuts-heart-disease-50-virender-sodhi.

Xun and colleagues, on the other hand, discovered no link among toenail selenium levels and indicators of sub-clinical atherosclerosis in young American adults. CHD data from the national addition of selenium-enriched fertilizers in Finland from the 1980s was reviewed in an intriguing Finnish report: Even though serum selenium levels were increased to an acceptable level (1.40 mol L1), incidences of CVD were unchanged between the pre- and post-supplementation periods. A U-shaped connection between blood selenium concentrations and cardiovascular mortality was postulated to account for these inconsistent observational results as well as long-term follow-up information from the US National Health and Nutrition Examination Survey (the NHANES research).

Antioxidants have been recommended as a feasible co-treatment for CHD due to growing evidence for the role of oxidative stress in the pathogenesis of hypertension. However, the evidence for a link between arterial blood pressure and blood selenium in adults is mixed. On the one hand, men with higher baseline selenium levels were found to have a decreased risk of hypertension. Data from the Cologne Analytic Lipid cohort, however, suggest that higher levels of serum selenium have been correlated with

greater blood pressure and higher hypertension incidence.

In conclusion, epidemiological studies have various confounding elements that make analysis and generalization difficult. Recent information on whether serum levels of selenium are dependable biomarkers in heart disease development or surveillance is scarce and does not provide a more definitive picture. The evidence on the function of selenium serum levels in CVD is mixed and conflicting. It is challenging to apply what we have learned from interventional supplementation research to the role of selenium as a biomarker and vice versa.

In addition to blood selenium levels, direct measurements of selenoproteins as biomarkers have been evaluated in heart disease. The septic shock diagnostics of selenoprotein P in comparison to GPx are superior in this case. Initial studies have reported their role in CHD and atherosclerosis. Further tests in the broader cohorts of patients are however required for the provision of accurate data on early diagnosis use and use for the medical practice of selenoprotein P and other cardiovascular (CVD) biomarkers.

Oxidative damage is critical in the immediate phase after a myocardial infarction, particularly after reperfusion. The mitochondria are a key source of cardiac ROS, and their production is connected to glutathione. GPx, thioredoxin reductases, and methionine sulfoxide reductase B1 have been associated to cardiovascular stress more than the other 25 selenoproteins known today. A small research of 55 patients with acute myocardial infarction found a link between the degree of myocardial infarction as defined by peak Troponin I release and serum selenium levels. Low selenium concentrations had no influence on stable angina pectoris in the AtheroGene trial, but they were linked to future cardiovascular death in individuals with acute coronary syndrome (Cooper, 2021).

5.3.3. Prophylaxis Selenium Supplements

Low selenium dietary intake, described as genuine selenium deficiency or reduced serum/plasma selenium concentrations, is identified as a risk factor for CVD, according to existing information collected from high-quality perspective research. However, results from selenium supplementation trials are still equivocal and show no significant advantages (Figure 5.10).

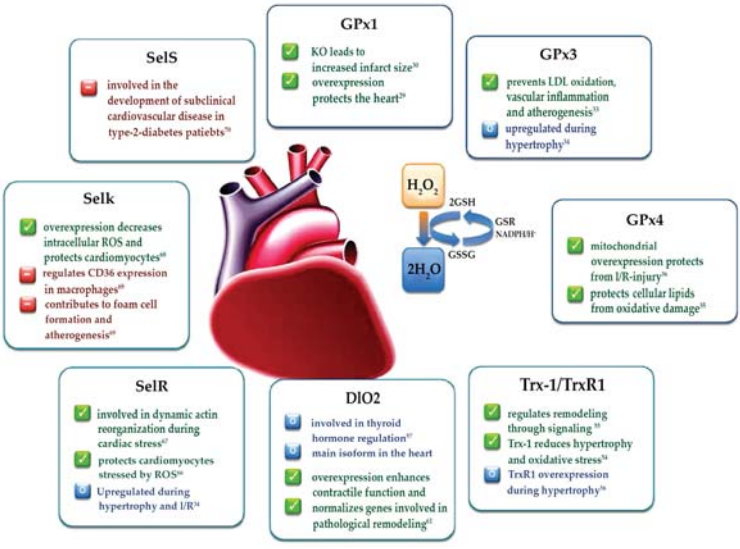

Figure 5.10. Even though selenium's relation to activities in the initiation and progression of cardiovascular disease has been studied for decades, both epidemiological and therapeutic trials of selenium supplementation remain unclear and are discussed in this review. The present state of knowledge on selenium and selenoproteins in the human body, as well as their physiological involvement in the cardiovascular system, is covered in this review. The association between selenium intake/status and a variety of health outcomes is examined, with a focus on cardiomyopathy, myocardial ischemia/infarction, and reperfusion injury.

Source: https://www.mdpi.com/2072-6643/7/5/3094/htm.

Few randomized controlled studies (RCTs) have looked at the impact of high-dose selenium on significant cardiovascular outcomes thus far. Flores Mateo and colleagues established a statistically substantial inverse connection between selenium levels and the occurrence of atherosclerotic CHD after combining 14 studies (n = 17,776 patients) in a comprehensive review and meta-analysis of the literature. In addition, four RCTs that supplemented antioxidant cocktails with selenium (daily doses ranging from 75 to 200 g) and other trace minerals and vitamins found no benefit in clinical outcomes.

A further meta-analysis published in 2014 found no substantial impact of selenium supplementation on overall mortality, CVD death rates, or all lethal and non-fatal cardiovascular events. It included 12 trials and

over 19,000 participants. In addition, non-high-density lipoprotein (non-HDL) cholesterol levels were shown to be much lower. Despite this, the consequences of selenium deficiency on lipid profile are only partially understood. In fact, the Supplementation with Antioxidant Minerals and Vitamins study from France found that selenium supplementation (100 g per day) was linked to greater triglyceride levels and lower HDL cholesterol levels in men. Furthermore, women who used selenium supplements had higher levels of cholesterol at the end of the study, and men were much more likely to take lipid-lowering medicines (Banuelos et al., 2002).

Excluding KD, there are no documented RCTs that have assessed the effectiveness of selenium supplementation in heart failure. In an animal model of Chagasic cardiomyopathy, previous research showed a poor prognosis, which was linked to low selenium levels. The STCC study currently evaluates the effective use of selenium intake at the daily dose of 100 μg sodium selenite all through 12 successive months as especially in comparison to placebo in adult people with mild or moderate global left ventricular systemic dysfunction.

There is currently inadequate evidence to support selenium therapy's beneficial effects in cardiovascular protection as a result, extensive observational studies and well-powered high-quality RCTs across populations from various geographical regions with varying levels of selenium intake are required. Moreover, the findings of trials should be differentiated by the patients' baseline plasma/serum selenium concentrations. Finally, the composition of selenium should be carefully studied, since whether selenium is active in its inorganic state (selenite and redox derivatives) or requires organification to accomplish its biologic activities is critical. Regardless, we presume that ever since large-scale, excellently RCTs are established, a phase II dose-ranging drug study with possible future controls in high-risk populations should be performed with the goal of determining the optimal and safe dose of chronic selenium consumption as a CVD prophylactic agent.

5.4. BENEFITS OF SELENIUM IN CARDIOVASCULAR SURGERIES

Annually, over 1 million patients require heart surgery around the world. Due to an aging population, demand is likely to exceed this figure in the coming decade. Despite significant progress in myocardial preservation methods, cardiac surgery still has a high risk of serious consequences. As

cardiac surgery is increasingly conducted on an elderly population with a greater number of concurrent medical illnesses and complex coronary lesions, the frequency will rise. Major side effects such as mortality, heart attack, cardiogenic shock and failure, renal failure, stroke, digestive issues, and dyspnea occur in up to 16% of all patients after their first admission to the hospital, according to data analyzed from patient databases. Ischemia, reperfusion damage, and preoperative inflammation are the three main pathophysiological pathways linked to the bulk of these systemic problems.

Patients having on-pump cardiac surgery are exposed to a variety of ischemic stimuli, including (a) micro embolic events, (b) cardioplegic arrest, (c) myocardial reperfusion by surgical revascularization, and (d) cardioplegic arrest termination. These factors cause hypotension, tachycardia, leukocytosis, pyrexia, organ failure, and tissue fluid accumulation, all of which have been linked to an inflammatory response. Because of this knowledge of the causative pathways, many treatments have been used to lessen the stress response, reduce organ failure, and enhance patient outcomes following cardiac surgery.

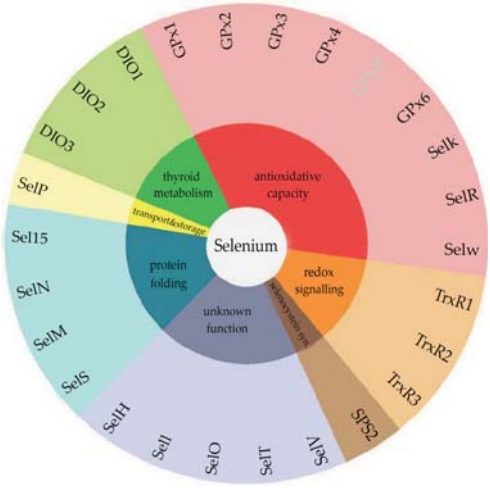

Figure 5.11. Cardiac surgery, particularly when a cardiopulmonary bypass is used, can produce a lot of reactive oxygen species (ROS), which can harm other organs and cells. Selenium supplementation can minimize this damage by promoting selenoprotein production, which increases H_2O_2 and other peroxide inactivation.

Source: https://www.mdpi.com/2072-6643/7/5/3094/htm.

There are pharmacologic and non-pharmacological ways to addressing distinct components of this pathophysiological process including as preoperative glucocorticoid treatment and off-pump surgery. Selenium is thought to have therapeutic characteristics in cardiac surgery patients at each step of the stimulus-to-organ-injury cascade. In the antioxidant intracellular network, selenium, and its antioxidant selenoenzyme GPx can neutralize both forms of free radicals. As a result, a new observational study looked at the preoperative selenium time course. Surprisingly, most cardiac surgical patients already had a considerable selenium shortage before surgery, which was exacerbated intraoperatively. Furthermore, a decrease in circulating selenium levels during surgery was involved in the onset of postoperative multi-organ failure. Low preoperative selenium concentrations have been connected to the development of postoperative organ dysfunctions, according to Koszta and colleagues (Figure 5.11).

These findings have prompted several clinical trials to assess the efficacy of selenium supplementation. Seven clinical studies addressing the function of selenium in patients undergoing heart surgery have been discovered. Two trials have yet to be completed. Enrollment in one of these ongoing trials is complete, but the results are still being published. In addition to the observational studies mentioned earlier, one open-label experiment investigated the efficacy and safety of high-dose selenium supplementation in heart surgery patients. In compared to a historical control group, the investigators discovered a considerably lower level of organ harm on the first postoperative day (Bailey, 2017).

The effectiveness of selenium supplements on patient outcomes was assessed in three double-blind, randomized controlled experiments. While two trials are continuing, the findings of a randomized controlled trial conducted by Leong and coworkers showed that patients who got a metabolic treatment along with a prescription of selenium had a much lower risk of myocardial damage. However, in this investigation, the impact of other antioxidants besides selenium cannot be ruled out. Given the scarcity of data, large, well-designed randomized clinical trials are still required before any suggestions on pre-, peri-, or postoperative selenium prescription can be created to reimburse for pre-existing low selenium status and/or obtained selenium deficiency because of cardiovascular surgical procedures.

5.5. IN THYROID FUNCTIONING AND MENTAL HEALTH

Selenium can be found in soil as well as marine bivalves (such as oysters). In some places of Turkestan, China, and the Western United States, soil levels are relatively high. In New Zealand, Scotland, Finland, and other regions of China, levels are so low that cattle must be supplemented, or they may become sick. According to several gardening discussion forums, New England soils are not outstanding, and Texas soils, where many people grew up, are mediocre. And, along with several other sources, determining how much selenium you get from the soil is challenging because locations vary greatly, and some kinds of selenium are more accessible than others.

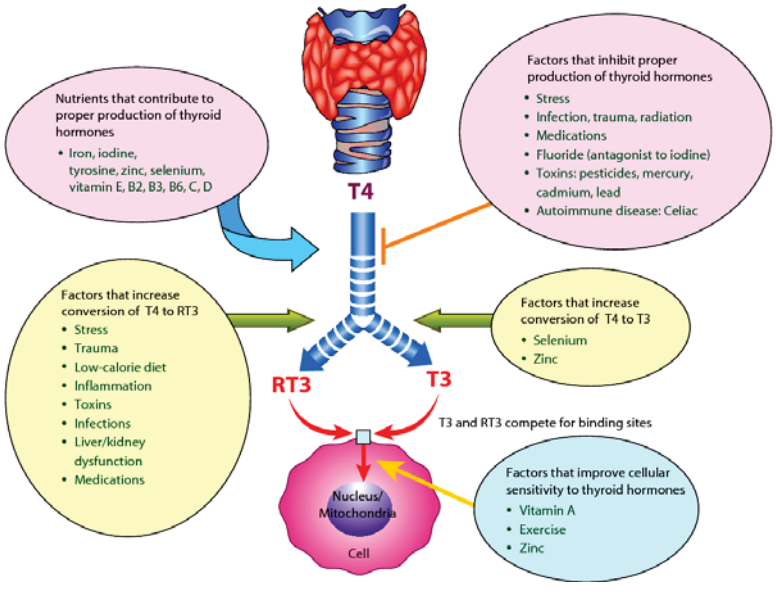

Figure 5.12. Since the identification of selenium as a constituent of an enzyme that activates thyroid hormone in the 1990s, the importance of selenium to thyroid function has been extensively researched. Selenium is generally acquired through meat, seafood, and grains, and is best recognized for the antioxidant capabilities of selenoenzymes. Because of variances in soil concentration and factors affecting its bioavailability to plants, intake levels vary around the world.

Source: https://www.semanticscholar.org/paper/The-Role-of-Selenium-in-Thyroid-Autoimmunity%3A-A-McGregor/2e00d428920212a7d28569ccfa6e708829893628.

Furthermore, selenium is essential for GPx, one of the body's major antioxidants. This compound protects our cell membranes' fragile polyunsaturated acids from oxidation (rancid). Because polyunsaturated fats, including those found in fish and a small proportion of poultry fats, are prone to being rancid, having plenty enzyme GPx on standby to preserve our cell walls is beneficial when we take these vital fats. We would not want to run out of the master antioxidants since that exposes us to a lot of toxic cruds accumulating in our bodies, which can have long-term consequences (Figure 5.12).

In China, selenium insufficiency is known as KD, a form of cardiac ailment. It is also suspected to play a role in cancers of the gastrointestinal tract, liver, and prostate. Furthermore, selenium appears to be necessary for thyroid hormone production when combined with iodine (specifically in converting inactive T4 to active thyroid hormone, T3). Selenium insufficiency appears to be one of the principal risks of a hastily devised ketogenic diet for the treatment of epilepsy in children, with an enlarged heart and irregular heart rhythm leading to mortality. Selenium insufficiency was additionally considered the reason for death (through cardiomyopathy) of grown-up patients on selenium-deficient TPN (all parenteral sustenance-given to patients in urgent conditions who, for reasons unknown, could not endure any food given by means of tubes or mouth in the gut).

Selenium is a minor element; therefore, it is suitable for people in trace amounts. Likewise, with practically all nutrients and minerals, since we need some does not mean more is better. People need micrograms as opposed to milligrams. Individuals have died (from lamentably low circulatory strain and cardiovascular failure) through the ingestion of gram measures of selenium, and toxicity happens at milligram sums. The principal indications of toxicity are hair and nail fragility, and garlic smell on the breath. Ingestion of gun bluing, which contains 2% selenious acid, can result in death from selenium poisoning. I would not advise drinking gun bluing because severe selenium toxicity appears to be one of the more dreadful ways to die (Buchs et al., 2013).

Selenium can be found in a variety of foods, including cereals, fruits, vegetable, livestock, and bivalves. Fruits and vegetables, on the other hand, do not appear to be abundant in the United States, and the best dietary source is really Brazil nuts (one ounce is able to provide one with over 500 micrograms, so take it advisable to have just a few at a time). Brazil nuts are also rich in omega-6 fatty acids and radium, which could be a cause to

avoid making them a regular part of your diet. Selenium is also abundant in organ meats.

A regular grain meal (pasta, oatmeal) will provide you around 10–15 mcg, but 3 ounces of salmon, steak, cod, and chicken breast would give you around 30 mcg. Though phytic acids in grains can prevent minerals from being absorbed, studies of women who ate wheat grown in selenium-rich soils revealed a significant increase in selenium levels in their blood. The RDA for adults in the United States is 55 micrograms (though a bit higher for breastfeeding or pregnant women).

Jaminet's doctors prescribe 200 mcg per day, but the US top tolerated limit is 400 mcg (Above this point, your nails become brittle, you become irritable and fatigued, and your breath becomes garlicky). Chinese trials of daily doses up to 1,500 micrograms, as well as another research of 600 micrograms daily, found no harmful effects. If your breath smells garlicky or your nails start to appear like this, cut back on the vitamins. (Actually, if your hair is falling out and your nails are looking like that, you should visit a doctor right now.) We now have a general understanding of what selenium is, where it originates from, and how much is too much. But how does this relate to the brain? The most selenium and mental health information appears to be linked to pregnancy, aging, and/or thyroid gland function.

Let us talk about a minute of pregnancy and depressive symptoms. It is a little-known belief that females are somewhat more depressed during pregnancy than afterward. This is what you get for parents and kids when you mix antenatal and postnatal depression statistics: Increased maternal self-care, increased alcohol use, decreased pregnancy medical attention, more eclampsia, issues of birth, preterm birth, lowered breastfeeding rate, lowered APGAR sleep ratings, sleep failure, cognitive impairment, greater risk of infirmity in babies, more problems with behavior.

There are other medical and social variables connected to prenatal depression but let 's concentrate on the dietary ones: Selenium, Omega 3, zinc, iron, calcium, vitamin B12, and folate status, have all been associated. In a thorough assessment of the literature, Kaplan, and colleagues discovered that vitamins, E, D, C, and B, choline, selenium, zinc, magnesium, iron, chromium, and calcium may have favorable impacts on mood disorders. A recent study found that pregnant women who were randomized to receive 100 mcg selenium daily from the first trimester till delivery had a significantly lower Edinburgh Postnatal Depression Scale score (which is favorable) (Figure 5.13).

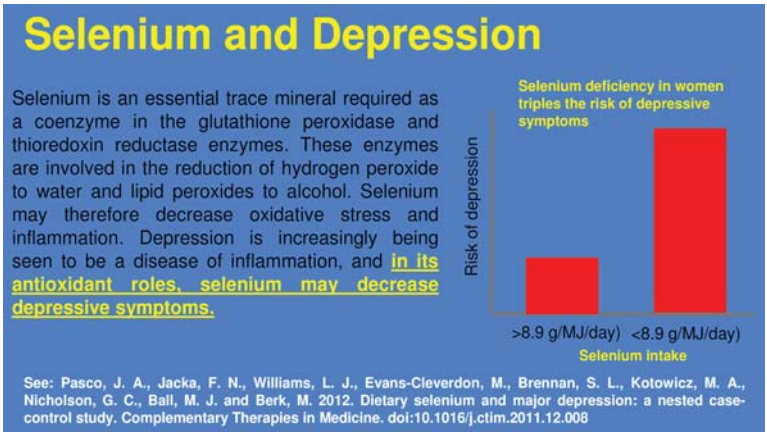

Figure 5.13. The potential of selenium to reduce inflammatory indicators and oxidative stress, improve endothelial function, and change serotonin synthesis and function appears to have a role in the development of depression. The modulatory impacts of selenium on thyroid metabolic rate, and the activity of selenoproteins in the noradrenergic, serotonergic, and dopaminergic systems, play a role in influencing an individual's vulnerability to depression.

Source: https://www.robertbarrington.net/selenium-and-depression/.

Thyroid hormones need selenium for metabolism and synthesis. Benton and Cook conducted a random supervised crossover study in 50 participants in 1991, using 100 mcg of selenium vs. placebo for 5 weeks, proceeded by a 6-month washout, and finally the crossover portion of the research. Supplementing with selenium was linked to improved self-reported mood. The brain is the last location where selenium levels decline when selenium is insufficient, according to the same article, implying that selenium is vital in the brain.

Gosney et al. comprehensively updated the impacts of micronutrient supplementation on emotions in nursing home occupants discovering that while no residents had inadequate serum concentrations of selenium to begin with, eight weeks of 60 mcg selenium intake (included along with a multimineral/multivitamin with 150 mcg iodine) was strongly linked with decreased depressive symptoms and increased serum levels. Selenium supplementation resulted in a decrease in blood thyroid hormone T4 and an increase in serum thyroid hormone T3, implying that the extra selenium helped the metabolically inactive T4 become the metabolically active T3. In other research, selenium serum levels were linked to older cognition.

Cognitive impairment was linked to lower selenium levels in a 9-year study of Alzheimer's patients (Badr et al., 2020).

We would not want to be low in selenium, especially if we have hypothyroidism, a history of mental disease, or are concerned about cognitive deterioration. With an average daily intake of 60–220 micrograms in the United States, many of us will have more than enough. Pregnant people, toddlers, the elderly, and individuals who eat nearly solely processed junk food should all be concerned about getting enough. Vitamins and minerals are almost usually best obtained through entire, unprocessed meals. It is good for your thyroid, heart, and mind. The thyroid gland contains the largest quantity of selenium in adults, and this mineral is important for the thyroid gland's ability to create thyroid hormone. Not only is getting enough selenium in your diet important for preventing thyroid disease, but it is also good for your overall health.

There are many thyroid issues that are associated with Selenium deficiency. Some of these include:

- Graves' disease;
- Thyroid cancer;
- An enlarged thyroid (Goiter);
- Autoimmune Hashimoto's thyroiditis;
- Subclinical hypothyroidism;
- Hypothyroidism.

To be correctly formed into thyroid hormone, iodine—the building block and crucial ingredient—requires selenium. While selenium is essential for your thyroid, selenium insufficiency is uncommon in the United States due to selenium-rich soil. Daily, most Americans readily obtain the needed quantity of selenium. While most people have a modest risk of developing a deficit, some persons have a higher risk. The following are some of the risk factors for selenium deficiency (Figure 5.14):

- Having human immunodeficiency virus;
- Undergoing kidney dialysis;
- Living in an area with selenium-deficient soil;
- Having had gastric bypass surgery;
- Digestive, intestinal, or absorption issues such as Crohn's disease.

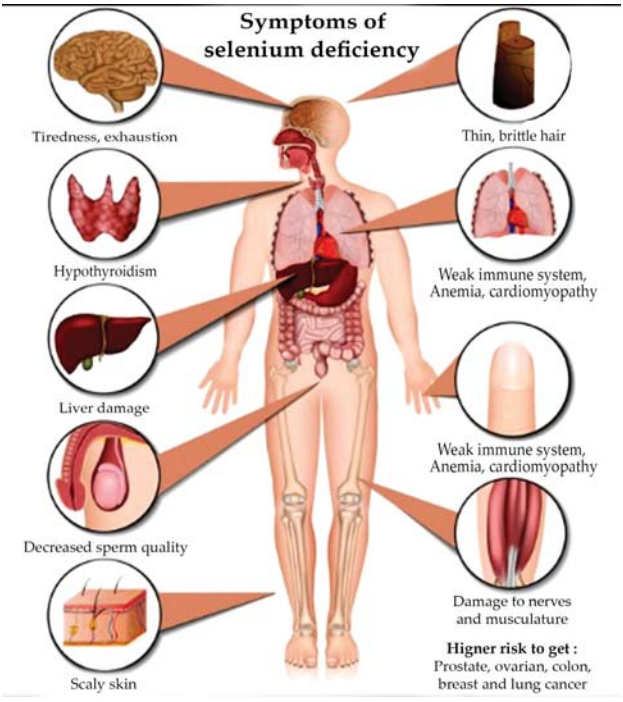

Figure 5.14. Selenium insufficiency has also been linked to problems with human growth and reproduction. Myodegenerative disorders, such as muscular weakening, are linked to moderate deficiency. Low selenium levels have been linked to depression, worry, and perplexity. The amount of selenium in most parts of Europe is far lower than in the United States. Eastern Europe has a lower average selenium intake than Western Europe.

Source: https://www.alamy.com/selenium-deficiency-medical-vector-illustration-isolated-on-white-background-infographic-image331011407.html.

When you do not get enough selenium, you can get a variety of symptoms. The following are a few of the most common:

- Difficulty concentrating and/or thinking;
- Compromised immune system, causing one to often get sick;
- Weight gain;
- Fatigue;
- Loss of hair;
- Infertility.

It is worth mentioning that some of these symptoms are like those of thyroid disease. Blood tests can be used to determine your selenium levels, or a hair or nail analysis can be used to track your levels over months or years. A normal blood level of selenium is 8 micrograms (mcg)/dL or greater, as per the National Institutes of Health. Although that is not a common test for thyroid disease (it has normally only done if a selenium deficit or toxicity is detected), you or your physician may wish to check your levels to make sure they are within normal parameters at some point.

5.6. IN THE IMMUNE SYSTEM

Even though reasons of this necessity are not always entirely appreciated dietary selenium is required for optimal immune function. Selenium influences both the innate, or "nonadaptive," immune system and the acquired, or "adaptive," immune system. Barriers against infection, as well as nonspecific effector cells like macrophages, are all part of the innate immune system. T and B lymphocytes are the acquired system's principal effector cells, maturing in response to immunological challenges. Selenium deficiency impairs lymphocyte proliferation in response to mitogen, and it impairs leukotriene B4 synthesis in macrophages, which is required for neutrophil chemotaxis.

Selenium deprivation influences the humoral system as well; for example, in rats, IgA, IgG, and IgM titers are reduced, while in humans, IgM, and IgG titers are reduced. There is a significant selenium shortage in asthmatic endothelium cells, which leads to an increase in adhesion molecule production and increased neutrophil adherence. These and many other impacts of selenium on the immune system have been discussed recently, and we will focus on only a few effects on neutrophil function here (Bini, 2009).

The influence of selenium on neutrophil function is one of the most frequently studied links between selenium and the immune system. To aid in the destruction of microorganisms, neutrophils create superoxide-derived radicals. This mechanism strikes a balance between producing enough radicals to destroy invasive organisms while also protecting neutrophils from radicals. Although selenium shortage has little effect on neutrophil counts in a variety of species, it does impair key elements of their function.

In vitro, neutrophils from selenium-deficient mice, rodents, and cattle can eat infections but not kill them as effectively as neutrophils from animals that are selenium-sufficient. This faulty function has been linked to reduced

cytosolic GPx (GPx1) neutrophil activity, allowing free radicals created during the respiratory burst to destroy the neutrophils directly. This theory is supported by an examination of the rate of radical generation in activated neutrophils from mice.

In selenium-deficient mice and mice repleted by IP injection with between 2.5 and 1,000 g of selenium/kg bodyweight, the initial percentage of decrease of cytochrome c by neutrophils activated with phorbol myristate acetate was the same Only the neutrophils from the selenium-depleted animals were able to produce radicals for more than 10 and less than or equal to 45 minutes. Increased selenium status and GPx activity in neutrophils are required to continue producing radicals. The candidacidal activity of neutrophils was biphasic. Candidacidal activity rose from 9% to 14% when deficient mice were given exceptionally low doses of selenium (Figure 5.15).

Figure 5.15. The most important change caused by a selenium shortage in the human immune system is the inhibition of the immunological response to a bacterial or viral infection. The immune system's lymphocytes and other cells are quantitatively and functionally disrupted by selenium deficiency. The administration of suitable dosages of selenium boosts the body's defense response, according to research undertaken in recent years.

Source: https://www.lifelinediag.eu/en/selenium-an-effective-weapon-of-the-immune-system/.

Supplementing with selenium did not boost this activity until considerably greater doses were provided, which coincided with increases in GPx activity. According to the findings of these investigations, immune cells' ability to kill ingested organisms is regulated by more than one selenium-dependent activity or intracellular compartment. This is partly attributable to GPx1 activation. More research is needed to see if the earliest alterations in candidacidal action are influenced by phospholipid hydro peroxide GPx activity and a specific pool of GPx1, as well as cytosolic or mitochondrial thioredoxin reductase.

Selenium has a function in cell metabolism and neutrophil function. Other variables, such as thyroid hormone metabolism, which is hindered in selenium deficiency, may potentially influence their activity *in vivo*. Hypothyroidism has a negative impact on immunological function, impairing neutrophils' ability to respond to a challenge or invading organisms. Thyroid function can be influenced by stress by suppressing thyroid hormone metabolism. Type 2 iodothyronine deiodinase activity can be found in the thymus, although it is mostly restricted to tissues that require local generation of triiodothyronine from thyroxine for optimal activity. In selenium insufficiency, any impairment of type 2 deiodinase activity could affect the immune system by causing thymic cell growth and function to be suboptimal. Selenium is required for various aspects of cell-mediated immunity in addition to eliminating harmful bacteria and fungi. This covers the elimination of viruses as well as the death of cancerous cells. The GPx may act as a mediator for these selenium functions, albeit this cannot be causally linked to peroxide protection (Domokos-Szabolcsy et al., 2018).

GPx and maybe thioredoxin reductases, on the other hand, may impact eicosanoid synthesis to regulate inflammatory and chemotactically active chemicals. The lipoxygenase and cyclooxygenase processes use fatty acids from the (n-3) and (n-6) series as substrates; the former produces pro-inflammatory leukotrienes, while the latter produces thromboxane and prostaglandins. Selenium deficiency can promote the creation of pro-inflammatory chemicals, which can increase the risk of diseases including heart disease and cancer. Selenium deficiency in the diet is required for the activity of nearly every arm of the immune system. Supplementing with selenium can boost immune function in British people who eat diets that are acceptable by WHO standards but fall short of the British Recommended Daily Intake.

5.7. IN KASHIN-BECK DISEASE (KBD)

Kashin-Beck disease (KBD) is a chronic, debilitating degenerative illness of the peripheral joints and spine that is common in Japan. People in China, North Korea, and southeast Siberia are the most affected. With 0.64 million patients, KBD is common in 377 counties throughout 14 provinces in China. KBD is a condition that affects the metaphysis and epiphyseal plate in children. This causes several consequences, including bone deformity, growth retardation, joint enlargement, and functional impairment in many joints, which is a major human and social economic issue for everyone affected.

Furthermore, KBD can affect cartilage metabolism, promote lipid peroxidation, and alter selenium and sulfur metabolic processes. Only a few therapies are available to treat KBD since the cartilage's ability to heal itself is limited. Non-steroidal anti-inflammatory medications, sodium hyaluronate, physiotherapy, and chondroitin sulfate coupled with glucosamine, for instance, are all possible treatments. Furthermore, orthopedic surgeons have shown that surgery to correct joint abnormalities is advantageous.

Even though the pathophysiology of KBD is multifaceted, selenium insufficiency is one of the key environmental risk factors. Selenium has been provided in numerous extremely endemic places since the 1970s. A meta-analysis research included five randomized controlled trials (RCTs) and 10 non-RCTs found that selenium supplementation can prevent KBD in children. Another systematic study found that sodium selenite (Se) was beneficial in treating people who had already been diagnosed with KBD. Alternative selenium supplementation utilized to treat KBD include sodium selenite combined with vitamin E (Se+VE), selenium salts (Se salt), selenium enhanced yeast (Se yeast), and sodium selenite combined with vitamin C (Se+VC). There were limited direct comparisons of various forms of selenium supplements for the management of KBD at the time of the research (Figure 5.16).

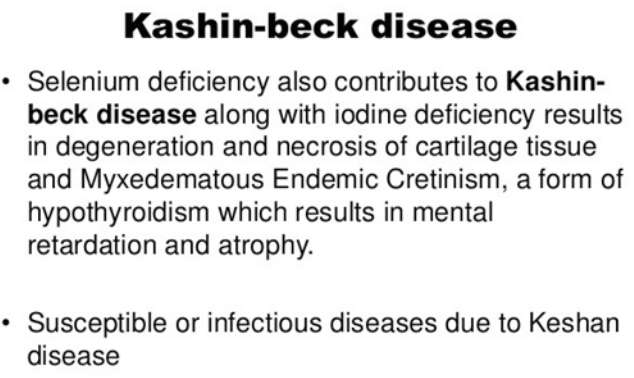

Figure 5.16. Selenium supplementation has been demonstrated to prevent this condition in selenium-deficient locations. However, selenium treatment had little effect in some places, indicating that selenium insufficiency may not be the primary cause of KBD. A substantial genetic link between COL9A1 SNP rs6910140 and Kashin-Beck disease was recently reported, suggesting that COL9A1 may play a role in the development of Kashin-Beck disease.

Source: https://www.slideshare.net/NiranjanGopal/zinc-and-slenium.

A comprehensive study and network meta-analysis (NMA) were conducted in response to the requirement for government policymakers and clinical care professionals to understand the consequences of a range of different possibilities. The goal of this study was to compare the efficacy of selenium supplementation in treating patients with KBD and to rate these selenium supplements depending on their performance. According to research, a selenium shortage is a critical factor in exposing target cells like chondrocytes to oxidative stress. Total soil selenium concentrations are typically modest in most heavily endemic areas. In a prior study, selenium levels in freshwater, soil, cereals, and maize were shown to be lower in endemic regions relative to those with low KBD rates. Furthermore, most people living in KBD-affected areas have low selenium nutritional status, as seen by low selenium levels in their serum, red blood cells, hair, and urine.

Many studies have proved the usefulness of various ways of selenium supplements for children, namely Se salt, Se enhanced yeast, oral sodium selenite tablets, spraying Se on plants, and Se enhanced fertilizer. Selenium supplementation was linked to a lower prevalence of KBD and a higher selenium concentration in the hair of people who reside in KBD-affected areas. In 1990, the incidence of radiological evidence of metaphysical

lesions of the hands in children aged 7–12 years was reported to be 44.8% in Cuimu, Shaanxi province. The frequency of these X-ray findings reduced to 0.3% in 2010 after the introduction of comprehensive KBD preventative strategies, particularly the use of Se salt. The low incidence of KBD may also explain why no studies on Se therapy for KBD have been reported in recent years (Charya, 2017).

According to the present NMA, all forms of Se supplements were more efficacious in curing KBD in children than the placebo. Se salt was shown to be the most effective, trailed by Se+VE, Se enhanced yeast, Se, Se+VC, VC, and placebo/no therapy. Because the information accumulation reliability was low (or exceptionally low), the SUCRA values for each comparison should be viewed in conjunction with the GRADE confidence in the estimates. The quality of the evidence is insufficient to determine which form of selenium supplementation is the most beneficial. In endemic locations, Se salt can be a cost-effective and practical technique for managing KBD. Overdosing on selenium, on the other hand, is dangerous. To avoid negative health effects, appropriate dosages should be tightly controlled, and selenium content should be closely monitored.

Since KBD in children has mostly vanished, further trials involving RCT to establish the clinically significant benefit of any selenium supplements for children with KBD are quite improbable. There is currently no effective treatment for KBD-related cartilage degeneration in adults. Novel treatment strategies, such as gene therapy and tissue engineering, could be employed to treat KBD-related cartilage degeneration.

5.8. IN KESHAN DISEASE (KD)

Keshan disease (KD) is a type of endemic cardiomyopathy (heart disease) that primarily affects Chinese children and women of reproductive age. Although the disease has been observed for over a century, the name comes from a severe outbreak in Keshan County, northeast China, in 1935. Epidemics have been documented in a large span that stretches from Heilongjiang Province in the northeast to Yunnan Region in the southwest of China, and crosses topography, soil properties, climatic conditions, and demographic types. This condition can cause death and presents as an abrupt inadequacy of heart function or a persistent moderate-to-severe cardiac hypertrophy. Seasonal changes in the epidemic were observed, with maxima in the south in the winter and the north in the summer. The worst periods were 1959, 1964, and 1970, when the yearly frequency was over 40 for

every 100,000, with over 8,000 illnesses and 1,400–3,000 fatalities every year. Even though the disease struck a wide swath of China, all the affected districts were isolated and had a high proportion of poor farmers who relied heavily on their surrounding environment for food. WMD in animals was discovered in the same places, and additional research revealed that the soils and crops were deficient in selenium. KD was found in places where cereal crops provided 0.04 mg/kg of selenium and dietary selenium intakes is around 10 and 15 grams per day. Afflicted individuals had exceptionally low selenium levels, as determined by hair contents of 0.12 mg/kg (Xu and Jiang, 1986; Tan, 1989; Yang and Xia, 1995). Large-scale mineral supplements were conducted on 1- to 9-year-old children who were at significant risk of the condition based on these findings. Around 36,603 children received 0.5- to 1.0-mg sodium selenite pills each week in an experiment conducted in Mianning County, Sichuan Province, between 1974 and 1977, while 9642 children received placebo pills (Déon et al., 2017).

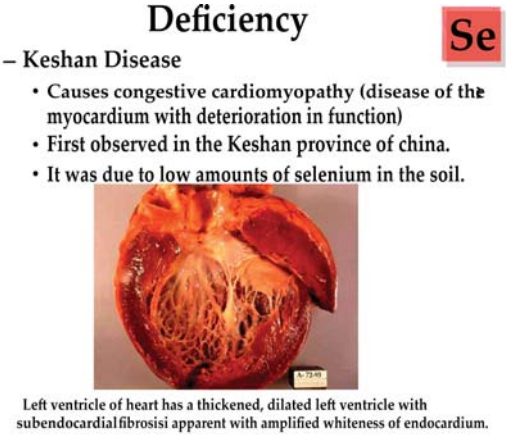

Figure 5.17. The coxsackie B virus had been related to Keshan. According to current research, a lack of selenium causes a more virulent strain of coxsackievirus to become the dominant viral species in a virus population, although the mechanism of this selection event remains unknown. Cancer, heart disease, high blood pressure, and stroke are all linked to Keshan disease. Psoriasis, eczema, rheumatism, blindness, alcoholism, and infections are among the other conditions that might affect a person.

Source: https://www.facebook.com/852539788140769/photos/a.852543548140393/1927728493955221/?type=3&eid=ARBLi5Wh5_Xa6nOZoxtEjA5Y-O0Y3jJSbATlJZXUa9Zs8d_oMdBtCum8RXOiknCY-PInbyeTa01ZynlFE.

Throughout the study's four years, the selenium-supplemented category had 21 instances of the illness and three fatalities, whereas the control group had 107 instances and 53 fatalities. By 1977, all the children had been given selenium supplements, and the sickness had disappeared in both groups. The findings revealed that taking 50 grams of selenite per day could prevent the disease, but that selenium had little therapeutic efficacy if the disease had already manifested (Anonymous, 2001). Even though the disease was selenium-responsive, the specific natural purpose of the mineral in the pathophysiology remained unclear, and the seasonal variation in disease incidence suggested a viral link. Following research revealed a significant incidence of the Coxsackie B virus in KD patients, as well as enhanced cardiotoxicity of this virus in mice with selenium and vitamin E insufficiency (Figure 5.17).

For many years, it was thought that selenium deficit lowered viral tolerance by impairing immune system; conversely, Beck (1999) found that a typically innocuous strain of Coxsackie B3 (CVB3/0) changes and became aggressive either with selenium-deficient or vitamin E-deficient mice. Even mice having normal dietary intake become sensitive to KD once the alterations are completed. These alterations in the virus are hypothesized to be caused by oxidative stress caused by a lack of vitamin E and selenium.

This study shows that selenium deficiency is important not only in the host's immunodeficiency but also in the infectious pathogen's lethality. Moniliformin mycotoxins produced by the fungus *Fusarium subglutinans, Fusarium proliferatum* in corn have been linked in several investigations as a probable cause of KD (Pineda-Valdes and Bullerman, 2000). KD is likely to be multifactorial, as is the case with many ecological illnesses, but selenium insufficiency is obviously a contributing component, even if it is not the primary cause.

KD's prevalence fell to less than 5 for every 100,000 in the 1980s, with fewer than 1,000 cases documented each year. The reasons for this are twofold: initially, prevalent selenium food fortification programs have been implemented in the vulnerable groups, and final, financial, and communication advancements in China, as well as the international community, mean that the population is becoming less reliant on locally grown foods in the diet. The disease's occurrence has decreased even further in recent years, to the point where it is no longer regarded a public health issue in China (Burk, 1994).

5.9. CONCLUSION

Selenium, an important trace mineral, is critical for human wellbeing. Selenium has architectural and enzymatic activity significance as a component of selenoproteins, with the latter being best-known as an antioxidant and catalyst for the generation of active thyroid hormone. Selenium is essential for immune response, and it seems to be a critical vitamin in preventing virulence and AIDS progression. It is necessary for sperm motility and may help prevent miscarriage. Deficiency has been connected to poor mental health. Although other illnesses involving oxidative stress and inflammation have demonstrated benefits of a greater selenium level, the findings have been ambiguous in relating selenium to CVD risk. Elevated selenium intake has been linked to a lower risk of cancer. This theory will now be tested in large clinical trials to confirm or disprove it. Low or declining selenium status in several regions of the world, particularly in some European countries, is causing worry considering these health impacts (El-Ramady et al., 2020).

It is important to remember that Selenium deficiency can cause a variety of health issues, including muscular tremors, hair loss, stomach disturbance, and lightheadedness, as well as more serious results such as cardiac arrest, breathing difficulties, and renal failure. Even when grown in low-selenium soil, Brazil nuts are extraordinarily high in selenium, with one nut holding more than the RDA. Consuming too many of these nuts on a regular basis, as well as supplementing with selenium more than the RDA, can lead to toxicity.

CHAPTER 6

EFFECTS OF SELENIUM INTAKE

CONTENTS

6.1. INTRODUCTION

The element Selenium (Se) is available in the world over, regularly in conjunction with sulfur containing minerals. It is regularly found in convergences of 50–90 μg/kg, however higher focuses can be related with some volcanic, sedimentary, and carbonate rocks. Selenium fixations in soils change broadly, from 5 to 1 200 000 μg/kg, being higher in soils of later volcanic beginnings. Selenium happens in soils in a few structures, as per its conceivable oxidation states: selenides (Se_2^-), formless or polymeric essential selenium (Se_0), selenites (Se_4^+) and selenates (Se_6^+). Selenium is a fundamental micronutrient for human wellbeing. Exposure and take-up happen primarily through the everyday eating routine. Selenium involves an extraordinary situation in natural general wellbeing due to the tight edge between admission that is healthfully adequate and that which is risky. Studies led on human populaces with overexposure to selenium from dietary sources have empowered the foundation of general wellbeing rules for selenium utilization to limit the danger of "selenosis," an unmistakable condition essentially affecting the skin, hair, and nails. A new screening appraisal by Environment and Climate Change Canada (ECCC) and Health Canada considered danger to human and natural wellbeing presented by selenium in the entirety of its structures. This appraisal credited danger of damage to organic entities and biodiversity coming about because of selenium and its mixtures. Progressing research likewise tries to characterize valuable or injurious connections between low selenium consumption and constant medical issue like coronary illness, diabetes, and disease (Feng et al., 2021).

6.2. ECOLOGICAL DESTINY

Acidic and diminishing conditions decrease inorganic selenites to natural selenium, while basic and oxidizing conditions favor the arrangement of selenates. Since selenites and selenates are solvent in water, selenium is filtered from very much circulated air through basic soils that favor its oxidation. Conversely, basic selenium and selenides are insoluble in water; thusly, selenium will in general be held in wet, ineffectively circulated air through soils, the decreasing states of which favor those structures. Along these lines, selenium in soluble soils is accessible for take-up by plants, though the accessibility of selenium in acidic soils will in general be restricted by the adsorption of selenites and selenates to press and aluminum oxide sols (Figure 6.1).

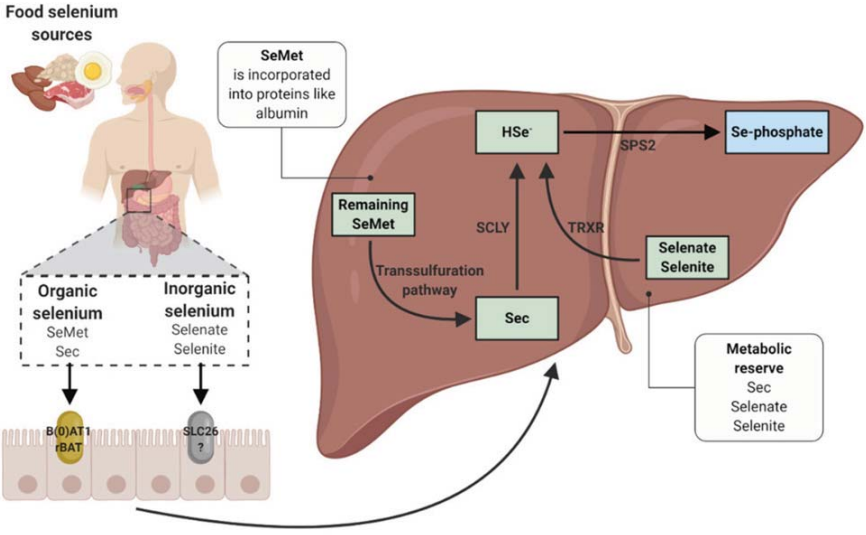

Figure 6.1. The relevance of selenium status in rheumatoid arthritis.

Source: https://www.mdpi.com/2072-6643/12/10/3007/htm.

6.3. ORGANOLEPTIC PROPERTIES

While basic selenium and numerous selenides have garlicky smells like their sulfur analogs, the prevailing types of selenium found in water, selenites, and selenates, are not odiferous. Accordingly, it is impossible that groupings of selenium regularly experienced in drinking-water will be perceivable by smell.

6.4. NATURAL LEVELS AND HUMAN EXPOSURE

6.4.1. Air

Selenium is delivered into the air as hydrogen selenide, created metabolically by plants, and as basic selenium, selenites, and selenates in particulate structure. The degree of selenium in most metropolitan air goes from 0.1 to 10 ng/m^3, however more significant levels might be found in specific regions, for example, nearby copper smelters (Figure 6.2) (Frankenberger et al., 2004).

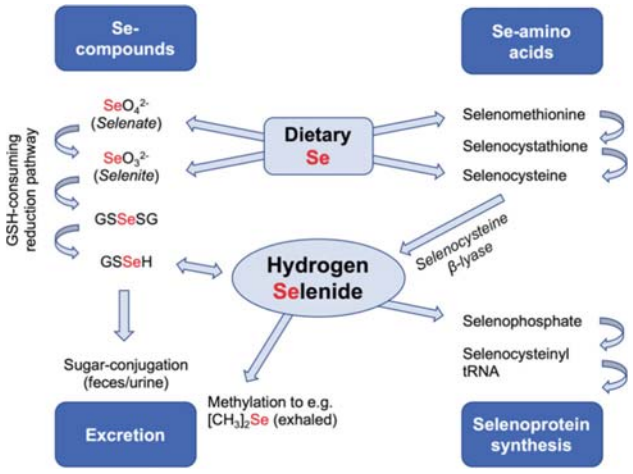

Figure 6.2. Selenium and hydrogen selenide: Essential micronutrient and the fourth gasotransmitter.

Source: https://icm-experimental.springeropen.com/articles/10.1186/s40635-019-0281-y.

6.4.2. Water

The degrees of selenium in groundwater and surface water range from 0.06 µg/l to around 400 µg/l. In certain spaces, selenium levels in groundwater can reach levels as high as 6,000 µg/l. Fixations increment at high and low pH because of change into mixtures of more prominent solvency in water. Levels of selenium in faucet water tests from public water supplies all throughout the planet are generally significantly less than 10 µg/l yet may surpass 50 µg/l. Drinking-water from a high soil selenium region in China was accounted for to contain 50–160 µg/l (IPCS, 1987).

6.4.3. Food

The vast majority acquire practically the entirety of their selenium from the food varieties they eat. In plant and creature tissues, selenium is discovered generally bound to proteins. Hence, the main food wellsprings of selenium are meats and fish (0.3–0.5 mg/kg), on account of their high protein substance, and oats (0.1–10 mg/kg), since they will in general be devoured in huge sums. Interestingly, food sources with somewhat low protein levels, like vegetables and natural products, will in general have moderately low selenium substance ((<0.01 mg/kg) (Garousi et al., 2016).

In all cases, the selenium content of food varieties mirrors the accessible selenium content of the soils used to deliver those food varieties (and the feedstuffs used to create animals). Appropriately, incredible varieties in the selenium content of food varieties happen, with high selenium food varieties created in pieces of the upper Great Plains of North America and detached territories in Venezuela and China. In China, the selenium content of corn, rice, and soy beans shifts from 0.005 to 45 mg/kg.

FAO/WHO (1998) noticed that worldwide selenium admissions change essentially; normal admissions were somewhat high in North America (85–150 µg/day), moderate in Europe (40–90 µg/day) and low in pieces of China (10–20 µg/day). In Europe, dietary selenium admissions have declined in ongoing many years: 29–39 µg/day in the United Kingdom and 30–80 µg/day in the Nordic nations in 1997 (UK EGVM, 2002), contrasted, and prior admissions of 40–90 µg/day. This decrease has been credited to decreases in the importation of higher-selenium wheat filled in North America.

6.5. RELATIONSHIP BETWEEN DRINKING-WATER TO SELENIUM ADMISSION

Most drinking-water contains centralizations of selenium that are a lot of lower than 10 µg/l, besides in certain seleniferous regions. In this manner, it would be uncommon for drinking water to make a huge commitment to add up to selenium admission. Indeed, even in high selenium regions, the overall commitment of selenium from drinking-water is probably going to be little in examination with that from locally delivered food.

6.5.1. Suggested Intake Amounts

Selenium is a fundamental component, and in this manner different public and international organizations have set up suggested every day admissions of selenium. The joint World Health Organization (WHO)/Food and Agriculture Organization of the United Nations (FAO) counsel on readiness and utilization of food-based dietary rules recorded suggested admissions of 6–21 µg of selenium each day for babies and kids, as per age, 26 and 30 µg of selenium each day for juvenile females and guys, individually, and 26 and 35 µg of selenium each day for grown-up females and guys, separately. In 2000, the United States National Academy of Sciences Panel on Dietary Oxidants and Related Compounds reexamined the prescribed admission of selenium to 55 µg/day for both genders and 70 µg/day for ladies in the course of pregnancy and lactation (Figure 6.3).

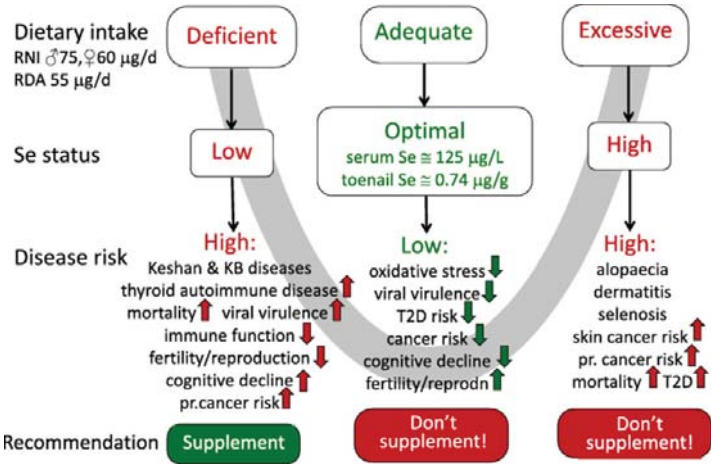

Figure 6.3. Selenium intake, status, and health: A complex relationship.

Source: https://link.springer.com/article/10.1007/s42000-019-00125-5.

Suggested selenium intakes are between 15 µg/day for babies 0–6 months old enough and 30 µg/day for children 4–8 years. The United Kingdom Expert Group on Vitamins and Minerals suggested selenium admissions of 60 µg/day for ladies and 70 µg/day for men. Notwithstanding, unmistakably the situation concerning selenium prerequisites is more perplexing than these proposals would recommend, on the grounds that a few gatherings, like New Zealanders and Swedish veggie lovers, have low admissions, equivalent to those in selenium-inadequate pieces of China, with no clear unfavorable impacts. Along these lines, different parts of the eating routine would seem, by all accounts, to be significant in moderating the impacts of low selenium admissions.

Due to worry about the unfavorable impacts coming about because of openness to inordinate degrees of selenium, different public and worldwide associations have set up maximum restrictions of openness for selenium. The United States National Academy of Sciences Panel on Dietary Oxidants and Related Compounds put forth an upper decent line for selenium at 400 µg/day. This level was additionally suggested by FAO/WHO and the United Kingdom Expert Group on Vitamins and Minerals. (Okonji et al., 2020).

6.6. ENERGY AND METABOLISM IN LABORATORY ANIMALS AND HUMANS

Most water-dissolvable inorganic and natural selenium compounds in food varieties are somewhat proficiently ingested across the gastrointestinal parcel (80–95%), albeit basic selenium and selenium sulfide are ineffectively assimilated. After ingestion, selenium is cleared by the liver and afterward shipped to fringe tissues by a particular carrier, selenoprotein P. Along these lines, selenium is dispersed to all organs, with the most noteworthy focuses happening in kidney, liver, spleen, testicles, and skeletal muscle. Selenium compounds are utilized thereby: to explicit selenoproteins, to vague proteins and to excretory elements (Figure 6.4).

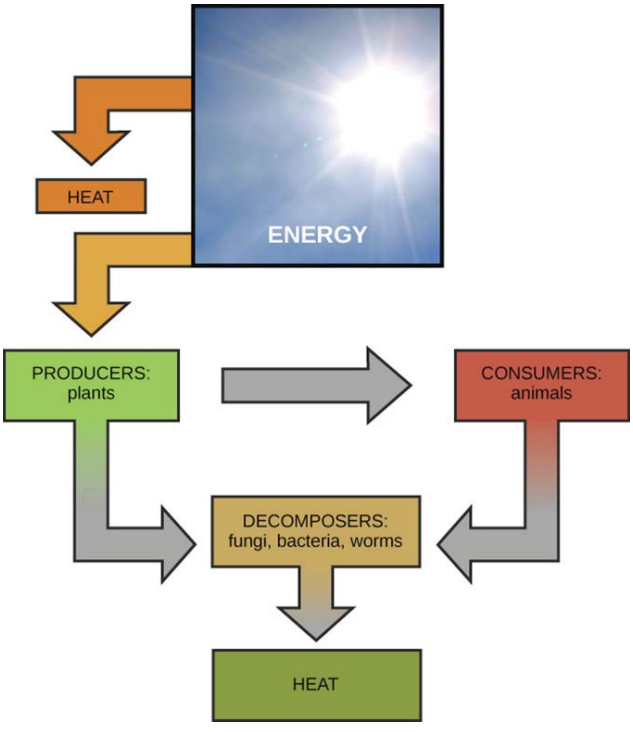

Figure 6.4. Energy and metabolism.

Source: https://courses.lumenlearning.com/suny-biology1/chapter/energy-and-metabolism/.

The healthfully fundamental elements of selenium have all the earmarks of being released by nearly 25 selenoproteins, every one of which contains

selenium as selenocysteine. This structure is not found in some other protein, being created by a novel co-translational change of those particular proteins. The particular selenoproteins incorporate glutathione peroxidases (GPx), thioredoxin reductases, 5-iodothyronine deiodinases, selenoprotein P and others. Assuming selenomethionine is devoured, that type of selenium can likewise be consolidated vaguely into proteins, as it can impersonate methionine in protein union. Numerous types of selenium (counting selenite, selenate, selenocysteine, and selenomethionine) are utilized to hydrogen selenide. While the last metabolite is the commit antecedent to the arrangement of selenocysteine in the particular selenoproteins, it can likewise be sequentially methylated (to methyl selenol, dimethylselenide, and trimethylselenonium particle) or changed over to a selenosugar and discharged.

6.7. IMPACTS OF SELENIUM CONTAMINATION OF WATER IN ANIMALS AND IN VITRO TEST SYSTEMS (FIGURE 6.5)

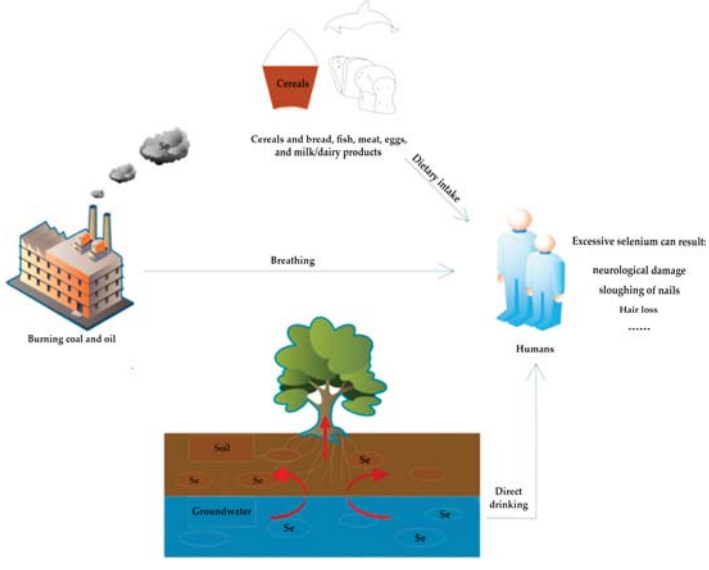

Figure 6.5. Selenium contamination, consequences, and remediation techniques in water and soils.

Source: https://www.sciencedirect.com/science/article/abs/pii/S0013935118301075.

6.7.1. Selenium Insufficiency in Creatures

Hardship of selenium can disable capacity and produce pathology in research facility creatures took care of low degrees of nutrient E or different cell reinforcements. Such pathologies incorporate skeletal and heart myopathies, encephalopathies, transudative diathesis and barrenness. Conditions identified with low focuses in the climate incorporate white muscle sickness in steers.

6.7.2. Intense Harmfulness

Selenite, selenate, selenocysteine, and selenomethionine are exceptionally poisonous and kill research facility creatures in single dosages of 1.5–6 mg/kg of body weight. In rodents, 5 mg of selenium for each kilogram of diet may bring about development decrease. At a dietary degree of 6.4 mg of selenium per kilogram (given as selenite), liver changes and splenomegaly happened. At 8 mg of selenium for each kilogram, frailty, pancreatic amplification, and expanded mortality were noticed (Tanmoy et al., 2019).

In light of development hindrance, clearly brought about by decreased discharge of development chemical from the foremost pituitary organ because of neighborhood selenium amassing, a no-observed adverse-impact level (NOAEL) of about 0.4 mg of selenium per kilogram of body weight each day was recommended. Hepatotoxic impacts have additionally been portrayed after dietary organization of selenium. In view of both development impediment and organ harmfulness, a least noticed unfriendly impact level (LOAEL) of 0.03 mg/kg of body weight each day has been recommended. The conditions “daze falters” and “soluble base sickness” have been depicted in animals devouring selenium aggregator plants. The commitments of plant alkaloids to these conditions stay muddled.

6.7.3. Conceptive and Formative Harmfulness

Selenate, selenite, selenocysteine, and selenomethionine are each teratogenic in avian species. Teratogenicity has additionally been seen in sheep and pigs. In examinations on monkeys (*Macaca fascicularis*) took care of selenomethionine (25, 150, or 300 μg/kg of body weight each day) during organogenesis, no indications of teratogenicity were noticed. Unfriendly impacts of selenate (3 mg of selenium for every liter in drinking-water) on propagation in mice and rodents have been accounted for, however there are likewise two negative reports on the impacts of selenite in hamsters and mice. Just at portions related with obvious maternal harming and healthful

hardship was proof of selenomethionine-initiated early stage or fetal poisonousness saw in bunnies and hamsters.

6.7.4. Mutagenicity and Related End-Focuses

A frail base pair replacement mutagenic movement has been shown for both selenite and selenate in Salmonella typhimurium strain TA100. Selenite, selenate, and selenide prompted unscheduled deoxyribonucleic corrosive (DNA) combination, sister chromatid trade and chromosomal abnormalities in cell societies *in vitro*, frequently within the sight of glutathione. In one *in vivo* study, chromosomal variations and expanded sister chromatid trade were found in hamster bone marrow cells after selenite treatment, however just at harmful dosages.

6.7.5. Cancer-Causing Nature of Selenium

Early examinations in which tumors were found in guinea pigs have been truly addressed on account of study limits, and a few evaluators have discovered the information to be uncertain. In two examinations on mice, there was either no increment or a reduction in the occurrence of tumors after the organization of selenite or selenate (3 mg of selenium for every liter of drinking-water) or selenium oxide (2 mg of selenium for each liter of drinking-water). Further information shows an anticarcinogenic impact of chosen selenium compounds. Seen altogether, this information appears to show that the mixtures examined won't go about as cancer-causing agents at low or moderate portions. Selenium sulfide given by gavage came about in hepatocellular carcinomas in rodents and mice however caused no expanded rate in tumors when applied to the skin of mice. Then again, selenite, selenomethionine, and some high-selenium food sources have been displayed to forestall or lessen carcinogenesis in each creature tumor model concentrated to date (for example Jackson and Combs, 2008). Creature examines have shown anticarcinogenic impacts for both inorganic and natural selenium compounds at portions more prominent than required for maximal selenoprotein articulation.

6.8. IMPACTS ON HUMANS

6.8.1. Insufficient Degrees of Admission

Low selenium status in people has been related with an adolescent, multifocal myocarditis called Keshan sickness and a chondrodystrophy called Kaschin-

Beck. While Kaschin-Beck sickness has not been very much portrayed, obviously selenium supplementation can forestall Keshan illness. All things considered, the etiology of Keshan infection has been hard to comprehend. Studies have revealed insight, notwithstanding; they recommend a job of a cardiophilic infection, the harmfulness of which expansions in selenium-insufficient hosts (Figure 6.6) (Hasanuzzaman et al., 2020).

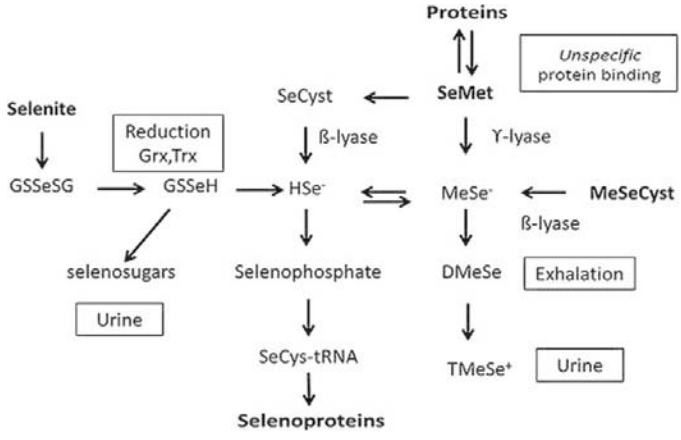

Figure 6.6. Treatment strategies in Alzheimer's disease: A review with focus on selenium supplementation.

Source: https://www.researchgate.net/publication/306242628_Treatment_strategies_in_Alzheimer%27s_disease_a_review_with_focus_on_selenium_supplementation/figures?lo=1&utm_source=google&utm_medium=organic.

A significant wellbeing focal point of selenium has been its application in anticarcinogenesis. That selenium can be anticarcinogenic was recommended during the 1960s dependent on an inverse relationship of malignant growth death rates in the United States of America (USA) and harvest selenium substance. Resulting considers discovered blood selenium levels to be conversely connected with the commonness of a few kinds of malignancy. The Nutritional Prevention of Cancer Trial showed that supplemental selenium (200 µg/day as high-selenium yeast) diminished dangers for complete diseases and prostate and colorectal carcinomas.

Even though only some other clinical trials have addressed this issue, most have indicated reduced most cancers threat related to selenium remedy, even though a recent one determined self-suggested selenium supplement use to be unrelated to prostate cancer hazard. evidence indicates several

mechanisms for selenium anticarcinogenesis: altered carcinogen metabolism, cell cycle law, immune surveillance, cellular demise programming, cancer cell migration and angiogenesis. As those effects occur at supranutritional selenium doses, their molecular bases would seem to involve a growth in selenium metabolite(s) under such conditions. studies factor to hydrogen selenide and its methylated metabolite methylselenol as energetic species, however selenomethionine may additionally play a role. Selenoproteins will also be involved, as differential cancer threat has been related to allelic variations of a few selenoproteins (Figure 6.7) (Hong et al., 2020).

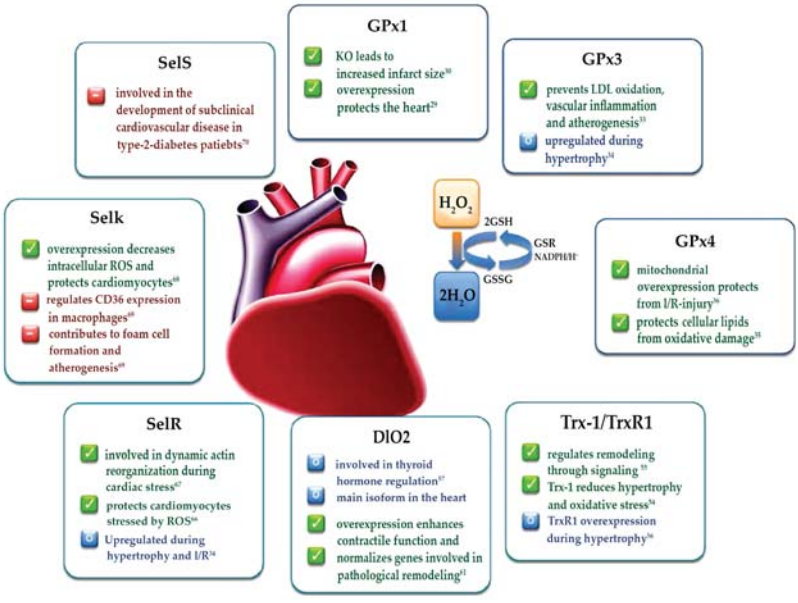

Figure 6.7. Roles of selenoproteins in the heart.

Source: https://www.researchgate.net/publication/275971086_Selenium_and_Its_Supplementation_in_Cardiovascular_Disease-What_do_We_Know/figures?lo=1&utm_source=google&utm_medium=organic.

6.8.2. Excessive Stages of Intake

Excessive nutritional intakes of selenium were diagnosed in elements of Venezuela, China, and South Dakota, USA signs and symptoms in humans with high urinary selenium degrees covered gastrointestinal issues, discoloration of the pores and skin and decayed. kids dwelling in a seleniferous region in Venezuela exhibited more pathological nail changes,

loss of hair and dermatitis than those living in Caracas. In China, endemic selenium intoxication has been studied Morbidity became 49% among 248 population of 5 villages in which the daily consumption was approximately 5 mg selenium. the principle symptoms had been brittle hair with intact follicles, lack of pigment in new hair, thickened, and brittle nails and skin lesions. signs of neurological disturbances were located in 18 of the 22 inhabitants of 1 heavily affected village handiest. those affected recovered as soon as diets have been modified following evacuation from the areas concerned. In a observe-up look at, it has been studied a population of approximately 400 people with average each day intakes starting from 62 to 1,438 μg. scientific signs and symptoms of selenosis (hair or nail loss, nail abnormalities, mottled enamel, pores, and skin lesions and adjustments in peripheral nerves) have been located in 5 of 439 adults having a mean blood selenium degree of 1,346 μg/l, corresponding to a everyday selenium intake of 1,260 μg. Decreases in prothrombin time and within the attention of glutathione in blood were seen at nutritional intakes exceeding 750–850 μg/day.

In a examine wherein 142 subjects from geographical areas where the average selenium consumption was 239 μg/day (68–724 μg/day) have been examined over two years an affiliation between selenium consumption and elevated alanine aminotransferase (ALAT) stages in serum become determined but taken into consideration to be clinically insignificant. not one of the results, together with nail abnormalities, have been associated with selenium intake. One case of selenium toxicity immediately attributable to a water supply has been mentioned. A family turned into exposed for about 3 months to well water containing 9 mg of selenium in line with liter. They suffered from loss of hair, weakened nails and mental signs and symptoms, however they recovered once they stopped the usage of the water from the properly concerned (He et al., 2018).

People acquired about 350 and 600 μg of selenium per day via food regimen and selenium-containing yeast for 18 months. Marginal hematological changes and a borderline increase in ALAT stages were seen. Degrees of selenium in serum and erythrocytes have been accelerated considerably in a small group of patients with rheumatoid arthritis who acquired each day supplements of 250 μg of selenium in selenium-enriched yeast in addition to selenium from meals for 6 months, in assessment with patients receiving placebo. The common nutritional consumption that is associated with selenosis is in excess of 900 μg/day.

The research via Yang et al. (1983) in China indicated that human beings residing in regions with multiplied selenium consumption of 750 µg/day confirmed no overt signs of selenosis; in the one's areas wherein selenosis turned into obvious, consumption became about 3–6 mg/day. In different areas, consisting of South Dakota, America, where intake was similar to that in areas of China laid low with selenosis, there have been no obvious unfavorable effects. this could reflect differences in dietary status, but a examine of people taking supplements did not find damaging results at intakes of 1.6 mg/day; negative outcomes had been suggested with the aid of a set taking 3.2 mg of selenium in keeping with day, but those outcomes did not coincide with levels of blood selenium (Figure 6.8).

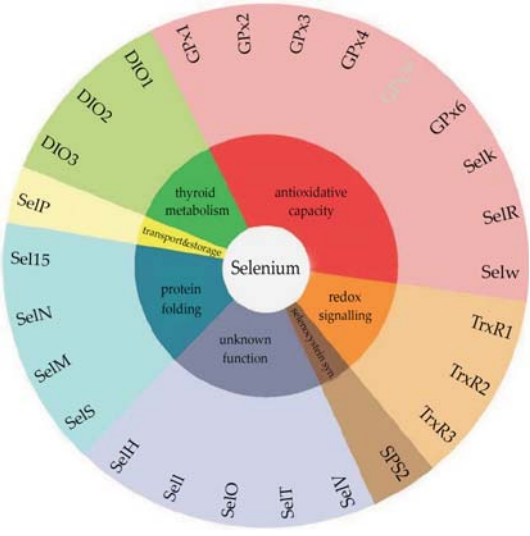

Figure 6.8. Classes of selenoproteins and their putative functions.

Source: https://www.researchgate.net/publication/275971086_Selenium_and_Its_Supplementation_in_Cardiovascular_Disease-What_do_We_Know/figures?lo=1.

6.8.3. Sensible Components

1. ***Analytical Strategies and Achievability:*** Atomic absorption spectrometry with hydride generation is the maximum convenient method for determining selenium in ingesting-water. If 100 ml samples are used for recurring analysis, the detection restriction is ready 0.5 µg/l. Inductively coupled plasma/mass spectrometry is also used, with a similar detection restriction.

2. ***Remedy and Manage Methods and Performance:*** The most common sorts of selenium in water are selenite (Se(IV), SeO_3^{2-}) and selenate (Se(VI), SeO_4^{2-}). The formation of selenate from selenite is sluggish, and each forms exist together in answer. Neither may be oxidized or decreased easily. Selenate is greater hard to take away from water by using techniques such as coagulation compared with selenite; therefore, oxidation of selenite to selenate might be unwanted in this context. It has been mentioned that chemical explanation with lime, ferric sulfate or aluminum sulfate and activated carbon adsorption are fairly effective in doing away with selenite from water and ineffective at disposing of selenate.

Checks have shown that the finest elimination changed into finished by clarification with ferric sulfate at a pH below 7 (Culp/Wesner/Culp, 1986). Selenium can be adsorbed onto iron oxide-lined sand. almost whole removal of Se(IV) from a 10 mg/l solution in contact with a 100 g/l lined sand was done inside 10 min, whereas Se(VI) elimination required about 90 min. The adsorption ability was about 1 mg/g of coated sand (Kaur et al., 2021).

Similar outcomes have been suggested the use of aluminum oxide-lined sand, despite the fact that the adsorption capacities were lower—about 0.5 mg/g for Se(IV) and 0.25 mg/g for Se(VI) remedy of herbal water containing 4 µg/l selenium with iron(II) hydroxide at pH 8.8 decreased the attention to underneath 1 µg/l. Selenium can also be removed the usage of zero-valent iron, which bureaucracy iron oxyhydroxides as corrosion products. less than 4% elimination of both Se(IV) or Se(VI) could be acquired the usage of 100 mg/l powdered activated carbon to deal with well water spiked with selenium at 0.03 and 0.1 mg/l.

The pH did no longer have an effect on the consequences. Pilot plant trials have shown that adsorption by using soil has the capability to eliminate selenium from water. Selenium elimination of 95% become done inside the absence of nitrate. The presence of nitrate interferes with the adsorption of selenium. its miles mentioned that activated alumina adsorption using Alcoa F-1 can led to selenium removals of 98% at pH five other studies have showed that ion exchange the use of artificial resins is capable of removing Se(VI) anions from groundwater. This observe as compared the potential of the synthetic resins with an amine-modified coconut coir (MCC-AE) and pronounced that MCC-AE may be used as a low-fee adsorbent/ion exchange for the remedy of anion-infected groundwater.

Laboratory research cautioned that each selenite and selenate may be eliminated through ion change and reverse osmosis. Cellulose acetate and cellulose triacetate membranes had been powerful at removing each selenite and selenate; removals in excess of 95% were done. A 95% elimination of selenium changed into executed by nanofiltration of noticeably infected agricultural drainage water all through laboratory studies. There are few, if any, reported statistics at the chlorination of selenium in water, and the subsequent guidance is consequently general in nature. below surprisingly harsh situations, chlorine will oxidize selenite to selenate, but this seems unlikely to be the case beneath water treatment situations. Selenium is unlikely to react with ozone, chlorine dioxide or chloramines.

6.9. PROVISIONAL TENET VALUE

Selenium is a vital detail for humans, and there are indications that selenium fame can be marginal in many components of the world, inclusive of western Europe. The capability for negative outcomes from selenium deficiency appears to be depending on a number of factors, which include average health and dietary fame. excessive intakes of selenium are related to a number of specific sicknesses and the capacity for detrimental results, however, once more, this seems to be strongly influenced by other elements. The capability for diffused biochemical outcomes which could affect the incidence of illnesses along with cancer and cardiovascular sickness remains unsure, for each low (i.e., extended prevalence) and excessive intakes (i.e., accelerated, or decreased incidence).

Water is not normally a main source of selenium consumption; however, it is miles important that a proper stability be performed between advocated intakes and unwanted intakes in figuring out the best guideline fee for selenium in drinking-water. while for maximum elements of the sector, the attention of selenium in consuming-water will not exceed 10 µg/l, there are situations in which selenium may be extended above everyday concentrations, and steerage can be required. wherein selenium consumption from the eating regimen is known, this need to be used in figuring out an awareness that guarantees that consumption is secure and enough. where selenium intake from the weight loss plan is not regarded, steering can be required. In figuring out a guiding principle fee, an allocation of 20% of the upper tolerable consumption of 400 µg/day to ingesting-water provides a sensible stability with a purpose to assist regulators and providers in making selections approximately whether further action is needed (Kunhikrishnan

et al., 2017). This gives a tenet fee of 40 μg/l. the selection of an allocation of 20% presents a huge margin to permit for people with an excessive consumption. the rule of thumb fee is particular as provisional because of the uncertainties inherent in the scientific database. For most Member States, a drinking-water tenet for selenium is senseless. wherein there are areas of high intake from a number of assets, of which drinking water can be one, then Member States ought to think about exposure from all assets in figuring out movements to lessen publicity. For ingesting-water, this could include the usage of alternative resources, blending low-selenium resources with excessive-selenium resources as well as considering selenium removal.

Selenium within the natural surroundings happens in several oxidative states that affect its bodily, biochemical, and toxicological traits. Selenium (Se79 34) is an evidently happening trace element discovered inside the earth's crust, basalt, and in sulfide ores of metals. A hint element found in coal that can shape both organic and inorganic compounds, selenium may also reach levels as much as 82 times its crustal attention. Selenium (Se) concentrations in uncooked coal are usually among 2 to 20 micrograms (μg) Selenium according to gram (g) Selenium commonly enters the food net when inorganic selenate (+6) or selenite (+4) species are converted via microbes, algae, and flowers to organoselenium compounds. In nutritional plant life (e.g., cereals, and greens) and meats, selenium is typically encountered as selenomethionine and selenocysteine, amino acids in which the sulfur atom in methionine and cysteine is changed by means of selenium.

An imidazole compound, selenoneine, turned into these days recognized because the foremost form of organoselenium present in fish and shellfish. different organoselenium compounds detected in fish encompass GPx, thioredoxin reductase and selenoprotein. Organoselenium compounds are the most common shape human beings consume via meals, whilst inorganic bureaucracy can be consumed via supplements or contaminants. Absorption of selenomethionine through active delivery may additionally exceed 95% and is greater than that of other organoselenium compounds, selenocysteine, and inorganic selenite and selenate. however, the absorption of selenocysteine, selenite, and selenate also are exceptionally efficient and of biological outcome.

Once absorbed, selenomethionine might also randomly substitute for methionine in muscle and plasma proteins, the latter component rendering it most green at growing blood selenium stages. With normal publicity to selenomethionine, constant kingdom blood selenium concentrations

are reached in about one month. other sorts of selenium, which includes selenocysteine, selenate, and selenite, are catabolized to selenide (–2), a number of which is modified to a natural shape and integrated into particular selenoproteins, appreciably the essential antioxidant enzyme GPx, and the service protein selenoprotein P, which transports selenium in plasma.

Selenoneine has been suggested within the blood of fish purchasers at excessive concentrations that depend on the frequency of fish intake. Selenium is excreted predominantly in the urine as various selenosugars that can be from the diet, e.g., muscle of marine fish. At high levels of selenium consumption related to selenosis, minor quantities of selenium can be expired as dimethyl selenide, which imparts a garlic odor to the breath. meals (together with supplements) are the number one supply of daily selenium consumption for the general populace, accounting for 99% of uptake. Organ meat and seafood usually include the highest concentrations (0.4 to 1.5 μg/g), followed through skeletal muscle meat (0.1 to 0.4 μg/g), and grains, nuts, and cereals (0.1 to 0.8 μg/g) (Lampis et al., 2014).

With a few wonderful exceptions, inclusive of Brazil nuts, end result and veggies incorporate exceptionally little selenium. Selenomethionine and sodium selenite are not unusual ingredients of multivitamins at 50 to 100 μg in keeping with tablet, and unique selenium dietary supplements can also contain 100 to 200 μg in step with tablet. according the 2011–2012 national fitness and nutrients exam Survey, the average daily selenium consumption in individuals' elderly two years and older from ingredients is 111 μg and from each ingredient and dietary supplements is a 130 μg. primarily based at the 2004 Canadian community health Survey, it changed into anticipated that the median nutritional selenium intake in adults ranged from 83 to 151 μg/day, with a 95th percentile intake as excessive as 236 μg/day.

Sure, subgroups of the population may be at risk of selenium consumption in extra of endorsed limits (discussed similarly underneath) in the event that they interact in frequent, if not different, consumption of grains and veggies harvested from distinctly seleniferous soils or fish caught in aquatic environments problem to selenium infection. Selenium bioaccumulates inside the aquatic surroundings and fish residing in waters challenge to emissions or runoff from coal and metallic mining, steel smelting and refining, and agricultural irrigation drainage may additionally have accelerated selenium content. It changed into envisioned that total selenium consumption may want to exceed 600 μg/day for First country residents eating fish at the 95% consumption level in the Elk Valley watershed of British Columbia that

changed into most contaminated from coal mining. Inuit groups in northern Canada whose traditional weight loss program consists of seals and Beluga whales that bioaccumulate obviously happening selenium may also ingest less than 600 μg Se/day at ≥ 90% intake ranges. excessive selenium levels can accumulate within the environment thru leaching from commercial activities, mining waste and anthropogenic emissions from the burning of coal.

Other business makes use of selenium compounds that would potentially be related to occupational exposure include metallurgy, glass manufacturing, chemical, and pigments, digital additives, and animal feed additives. industrial and mining-related operations account for nearly 40% of the selenium emissions into atmospheric and aquatic environments. Public consuming water materials in Canada and the USA normally include much less than 2 mg consistent with Liter (L), and consequently make contributions little to nutritional consumption. however, instances of excessive selenium exposure from properly water contaminated by using mining operations have been suggested.

Figure 6.9. Selenium sulfide shampoo.

Source: https://www.webmd.com/drugs/2/drug-8706/selenium-sulfide-topical/details.

Selenium sulfide is nowadays is regularly used in shampoos and topical medicines for remedy of seborrheic dermatitis and other skin situations but absorption through the pores and skin is negligible. Aquatic ecosystems and aquatic-established vertebrates are extremely touchy to selenium-laden water. Egg-laying vertebrates can have excessive levels of embryo mortality, while fish can go through larva deformities. herbal selenium concentrations

in aquatic structures regularly are not high sufficient to be toxic to ecosystem population (Figure 6.9).

However, ambient water concentrations of just 5 to 10 µg/L of selenium can rapidly bioaccumulate, causing toxicity within the meals net. Bioaccumulation of selenium in contaminated sediments may be cycled into meals webs for many years. preliminary selenium toxicity in adult fish often can move undetected whilst a hit replica is interrupted or fails. Maternal transfer, where high selenium concentrations are received by using eggs from Se-uncovered girls, is a properly-documented pathway for selenium publicity. when the eggs hatch, selenium is then metabolized with the aid of the developing fish. Environmental impacts from mining may be devastating and long lasting even after rehabilitation and reclamation. for example, poor practices and business sports have released toxic amounts of selenium into the surroundings, that can decimate natural world populations. This impact changed into proven within the 1970s North Carolina Belews Lake, where complete populations of reservoir fish were removed and long-time period affects to the surroundings have been observed due to electricity plant waste discharges containing excessive amounts of selenium (Lenz and Lens, 2009).

Sizeable impacts—due to increased selenium concentrations—on sensitive ecosystems and human health inside the Crown of the Continent area will compound as industrial and mining operations expand. Ongoing studies of water and biota characterize impacts from a history of coal mining pastime in the Elk River basin of southeastern British Columbia, together with lengthy-term will increase in selenium concentrations over the years in water downstream of the Elk Valley River coal mines. The Elk River flows into the Kootenai River and has impacts on downstream US waters. current tracking efforts via a partnership of us state, federal, and tribal organizations verify increases in selenium concentrations over the years in water and fish tissue downstream and to the south of the Elk Valley River coal mines in Lake Koocanusa.

It may further negatively affect human fitness whilst everyday nutritional exposures of selenium are blended with assets from human activities. Selenium infection in aquatic ecosystems can motive a cascade of bioaccumulation activities which regularly can expand the time-frame for intervention and recuperation efforts over a few years. preventing impacts from selenium due to mining and fossil gasoline burning may require vigilant threat control procedures and threat tests based on water monitoring and achieving water nice dreams to assist in heading off threats

to the environment and human fitness. Whole blood selenium is considered the maximum beneficial biomarker of intermediate to lengthy-time period selenium exposure. within the 2011 to 2012 cycle of the USA national health and nutrition evaluation Survey, representative values for selenium in entire blood for the USA population had been 190 µg/L (geometric imply), a 190 µg/L (50%) and 236 µg/L (95%). Corresponding values stated inside the Canadian health Measures Survey cycle I (2007 to 2009) were 202, 200, and 253 µg/L (Lemaire et al., 2021).

6.10. SELENIUM PUBLICITY TIPS

Selenium is an important element in human nutrients. It performs a role inside the characteristic of several proteins (selenoproteins) and enzymes, in particular the ones concerned in redox regulation and pathways, thyroid hormone movement, immune response and irritation. but, as formerly noted, there seems to be a totally modest distinction between tiers essential for these wholesome capabilities and degrees related to acute or persistent health effects.

Of all trace factors, selenium has the narrowest margin between consumption—that is required for human nutritional needs—and that is unsafe to health. despite the fact that some experimental studies suggest that inorganic selenium exerts greater toxicity than organoselenium following acute or subacute high dose ingestion, uncertainties continue to be concerning the differential toxicity of selenium species following long term dietary exposure, and modern-day consumption suggestions observe similarly to all chemical paperwork. Selenium consumption steerage additionally has been developed without adjustment for the capacity presence of different dietary metals and metalloids with which selenium may additionally have interaction.

A precis of dietary recommendations is proven in Figure 6.10 (next page). In a record sponsored in component with the aid of the us department of fitness and Human services and fitness Canada, the Food and Nutrition Board (FNB) on the Institute of drugs of the national Academies mounted a recommended dietary allowance (RDA) for selenium in adults of 55 µg/day (20 µg/day in youngsters age one to three years). The encouraged nutritional Allowance—the common day by day degree of consumption considered sufficient to meet the nutrient necessities of almost all (97% to 98%) wholesome individuals—become based totally on intake associated with a maximal (or plateau) plasma awareness of the selenium established enzyme

GPx. an analogous parameter hooked up with the aid of the arena health organization (WHO), termed the endorsed Nutrient consumption, was set at 26 µg/day for females and 34 µg/day for men among 19 and 65 years of age.

The endorsed Nutrient consumption changed into based on a selenium consumption taken into consideration enough to maintain plasma GPx at two-thirds of maximal concentration. extensive uncertainty exists concerning the impact, useful or deleterious, of maximizing selenoprotein levels or enzymatic activity. The proposed safety furnished by using selenium in opposition to most cancers and chronic disease was not supported by randomized trials of supplementation. instead, current biochemical studies imply that selenium overexposure may also result in various poisonous impacts, which includes oxidative stress and the consequent exhaustion of antioxidant enzymes in reaction to this oxidative interest. This damaging response might also seem at lower concentrations than predicted (Figure 6.10).

Nutritional Criteria		World Health Organization (WHO)	Institute of Medicine National Academies (IOM)
Daily nutrition	Adults	26 µg/day females [1^] 34 µg/day males [1^]	55 µg/day [2+]
	Children	nr	20 µg/day [2+]
Tolerable Upper Intake Level (UL)	Adults	nr	400 µg/day [2]
	Children	nr	90 µg/day [2]

Figure 6.10. Summary of reported nutritional guidelines [nr = not reported].

Source: https://www.ijc.org/sites/default/files/2020-09/HPAB_Selenium-HealthReview_2020.pdf.

The Institute of drugs mounted a Tolerable upper consumption degree (UL) for selenium in adults of 400 µg/day (90 µg/day for youngsters age one to a few years) via applying an uncertainty element of two to a "no found unfavorable effect degree" of 800 µg/day discovered in the Enshi County, China selenosis outbreak. The UL is defined as the highest degree of nutrient intake (from meals and dietary supplements) this is "in all likelihood to pose no danger of detrimental fitness outcomes in almost all people." based on comparable statistics from Enshi, but making use of barely distinct "no observed unfavorable impact degrees" and uncertainty factors, the USA Environmental safety business enterprise (USEPA) established a "Reference Dose" and the us employer for toxic substances and disease Registry set up

a “minimal danger stage” for oral selenium consumption of 5 µg according to kilograms (kg) per day (µg/kg-d).

The “Reference Dose” and the “minimal risk level” equate to oral selenium consumption of 350 µg/day in a 70 kg adult. The biomonitoring equivalents in entire blood similar to the UL “reference dose” and “minimal hazard level” in adults are 480 µg/L and 400 µg/L, respectively. consuming water, ambient water and fish tissue pointers are shown. due to the fact drinking water is expected to supply a fraction of overall allowable daily intake, public health organizations have established policies or hints relating selenium in consuming water. these consist of the USEPA most contaminant degree for selenium in consuming water of 50 µg/L; fitness Canada most suitable concentration of 50 µg/L; the WHO provisional tenet cost of 40 µg/L; and the country of California public fitness purpose of 30 µg/L. Public fitness groups additionally have evolved screening values for selenium in fish potentially impacted through increased selenium of geologic or anthropogenic starting place, as expanded selenium ranges in aquatic species consumed through human beings might also adversely affect subsistence anglers (Ojeda et al., 2020).

The screening values—which may also vary in part based totally on whether or not the patron is a recreational or subsistence fisher—constitute stages that must cause web site-particular fish monitoring and advisories concerning endorsed ranges of intake. The USEPA evolved a selenium screening value in fish tissue of 20.0 parts in line with million (ppm) wet weight (ww) applicable to recreational fishers (average intake charge of 17.5 gram in line with day), and a couple of.457 ppm ww for person subsistence fishers (average intake of 142.4 gram according to day). extra these days, assuming a fish consumption charge of 54 grams in step with day through adults, a fish selenium screening cost of 7.7 ppm changed into suggested. This screening fee will vary at distinctive intake costs. California’s workplace of Environmental health danger assessment derived a fish contaminant purpose for selenium of 7.4 ppm ww for grownup leisure fishers. The British Columbia Ministry of environment and climate alternate method developed fish screening values for selenium of 1.8 ppm ww and 18.7 ppm ww applicable to high fish clients (average of 220 g/day) and occasional fish consumers (common of 21.5 g/day), respectively (Figure 6.11).

	Drinking Water Criteria	Ambient Water Quality Criteria		Screening Values in Fish Tissue	
		Lentic Waters	Lotic Waters		
WHO	40 μg/L [3] *	nr	nr	nr	nr
Health Canada	50 μg/L [4] **	nr	nr	nr	nr
USEPA	50 μg/L [5] ***	1.5 μg/L [6]	3.1 μg/L [6]	20.0 ppm ww [7] a	2.457 ppm ww [7] b
Alberta	50 μg/L [8] **	nr	nr	nr	nr
British Columbia	10 μg/L [9] **	2 μg/L [9]	2 μg/L [9]	18.7 ppm ww [9] c	1.8 ppm ww [9] d
California	30 μg/L [10] ****	nr	nr	7.4 ppm ww [11] e	nr
Idaho	50 μg/L [12] ***	nr	nr	nr	nr
Manitoba	10 μg/L [13] **	nr	nr	nr	nr
Michigan	50 μg/L [14] ***	nr	nr	nr	nr
Minnesota	30 μg/L [15] ***	nr	nr	nr	nr
Montana	50 μg/L [16] ***	nr	nr	nr	nr
North Dakota	50 μg/L [17] ***	nr	nr	nr	nr
Ontario	50 μg/L [18] **	nr	nr	nr	nr
Saskatchewan	50 μg/L [19] **	nr	nr	nr	nr
Washington State	50 μg/L [20] ***	nr	nr	nr	nr

Figure 6.11. Summary of reported drinking water, ambient water, and fish tissue guidelines [Nr = not reported; ww = wet weight]. Drinking water criteria ambient water quality criteria screening values in fish.

Source: https://www.ijc.org/sites/default/files/2020-09/HPAB_Selenium-HealthReview_2020.pdf.

In 2016, the USEPA issued an "aquatic life ambient water satisfactory criterion" for selenium purported to be defensive of the viability of freshwater fish populations (USEPA 2016b) to help protect subsistence or leisure harvests. To meet the fish tissue criterion, chronically exposed fish must have a muscle selenium focus of much less than 11 ppm (dry weight). The corresponding limits for selenium in water have been 1.5 μg/L, or additives consistent with billion (ppb) (lentic waters), and 3.1 μg/L, or ppb (lotic waters), respectively (see Figure 6.12). The time period lentic describes although waters, and lotic references actively moving waters. The occurrence of selenium in aquatic systems is attributed to nearby geology and mining interest. British Columbia ambient water suggestions are 2 μg/L. levels of selenium in waters shared with the aid of Canada and the United States will be predisposed to fall beneath cutting-edge recommendations for ingesting water in each country, even though some exceedances had been reported.

One such example includes extended selenium tiers within the Kootenai River downstream of the Elk River, spanning the border of Canada (British Columbia) and the USA (Montana and Idaho). To deal with this trouble,

recent work in addition south in the Lake Koocanusa atmosphere goals to become privy to water great standards for selenium degrees in the lake to protect touchy fish and different aquatic species), and is supported by using the use of Montana's branch of Environmental Protection and British Columbia's Ministry of the surroundings and climate change method, through a multistakeholder tracking and studies operating group. The monitoring and studies running organization additionally supports Montana's ongoing evaluation of its water first-class and fish tissue requirements. Whilst Montana and Idaho accompanied USEPA's requirements statewide, Montana also interests to expand more website-specific water and fish tissue standards for the Libby Dam location.

To date, no lengthy-time period studies of selenium consumption in residents of the affected watershed, with extraordinary aquatic intake styles downstream from Elk Valley coal mines had been carried out. Additional information can be useful to guard public health. To decrease potential human fitness risks, and in line with the example of Montana, further assist for the creation of site- or watershed-unique selenium thresholds and advisories may be warranted throughout the transboundary. At the identical time because the governments of Canada and the us have worked to address the fitness risks posed through accelerated selenium in aquatic structures within their borders, connecting these efforts for shared watershed systems alongside the border remains a task. As an instance, minimizing the floor disposal of mine waste and wastewater, and using practices much like the backfilling of solids or *in situ* water recycling, can lessen the capability of go-border selenium shipping in the surroundings (Papp et al., 2010).

Treating transboundary watersheds as a unit could make sure appropriate deliver controls and human fitness advisories regardless of place in the watershed. Efforts to mechanically display fitness and ecological information in transboundary aquatic systems at hazard for selenium contamination might boom public health safety in both global locations. Programs assisting more recurring selenium monitoring and reporting for water and fish in shared watersheds additionally ought to encompass provisions for regular sharing of fitness, ecological, and environmental statistics a number of the worldwide locations (Figure 6.12).

		Year	2017	2014	2013	2012	2011	2010	2009	2008	2007	2006	2001	1985	1975	1974	1973
Transboundary Basins																	
St. Croix River Basin[b]	# of Samples		10	10	12	8	4	14	20	nr	nr	nr	nr	nr	nr	nr	nr
	Min (µg/L)		<0.03	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	nr	nr	nr	nr	nr	nr	nr
	Max (µg/L)		0.07	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	0.1	nr	nr	nr	nr	nr	nr	nr
Souris River Basin[c]	# of Samples		16	16	16	18	19	13	18	14	16	18	nr	nr	nr	nr	nr
	Min (µg/L)		.036	.33	0.33	0.3	0.3	0.27	0.24	0.47	0.26	0.22	nr	nr	nr	nr	nr
	Max (µg/L)		1.2	.73	2.36	0.69	0.7	0.65	1.61	1.81	0.79	0.61	nr	nr	nr	nr	nr
Red River Basin Aquifers[d]	# of Samples		46	nr	nr	nr	nr	nr	nr	nr	nr	nr	144	nr	nr	nr	nr
	Median (µg/L)		nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	1.7	nr	nr	nr	nr
	Max (µg/L)		1.9	nr	nr	nr	nr	nr	nr	nr	nr	nr	21	nr	nr	nr	nr
Rainy River Basin Aquifers[d]	# of Samples		nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	39	nr	nr	nr	nr
	Median (µg/L)		nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	1.4	nr	nr	nr	nr
	Max (µg/L)		nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	308	nr	nr	nr	nr
Great Lakes Basin																	
Lake Superior Basin[d]	# of Samples		nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	56	nr	nr	nr	nr
	Median (µg/L)		nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	1.2	nr	nr	nr	nr
	Max (µg/L)		nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	93	nr	nr	nr	nr
Lake Ontario[e]	# of Samples		nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
	Median (µg/L)		nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	0.97	nr	nr	nr
	Max (µg/L)		nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	1.9	nr	nr	nr
Lake Erie (western)[f]	# of Samples		nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	6	6	12
	Mean (µg/L)		nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	2	1	4
	Max (µg/L)		nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
Canada/ US Drinking Water Guidelines for Se[a]	50 µg/L																

Figure 6.12. Reported selenium (Se) levels in select Canada-US transboundary watersheds [nr = not reported].

Source: https://www.ijc.org/sites/default/files/2020-09/HPAB_Selenium-HealthReview_2020.pdf.

6.11. SAMPLE TRAINING AND EVALUATION

6.11.1. Water and Sediment

Training and analysis of all water and sediment samples have been conducted with the useful resource of the BOR Soil and Water Laboratory in Bismark, ND. Water samples were digested using technique 3030E from well-known techniques for the exam of Water and Wastewater. Sediment digestions accompanied approach 3050B from EPA SW-846 take a look at techniques for comparing strong Waste (U.S. Environmental protection Organization, 1996). Water and sediment digestates have been analyzed for ordinary recoverable selenium by way of graphite furnace atomic absorption spectrophotometry following approach 270.2 as defined in techniques for Chemical evaluation of Water and Wastes.

6.11.2. Organic Samples

Training and evaluation of all biota samples become completed by using CERC. Small fish samples have been chopped and minced with a meat cleaver, but large samples were processed via a Hobart band observed and meat grinder. Invertebrate samples wanted no preliminary homogenization. All samples were lyophilized, and percentage moisture changed into decided alongside aspect the lyophilization system. Following lyophilization, invertebrate samples and small samples of fish were located in a Bamix® mixer/blender and automatically floor to a hard powder. For big fish samples, the dried cake product changed into hand-kneaded in a plastic bag to a rough uniform powder. every ground sample product became saved in a 40 ml glass vial in a desiccator previous to in addition remedy. Dried fish or invertebrate samples (~0.5 g each) had been subjected to a nitric acid-magnesium nitrate dry ashing device (Brumbaugh and Walther, 1989). The willpower of selenium in fish and invertebrates have become accomplished with the useful resource of flow-injection hydride generation atomic absorption spectroscopy. in this method, the digestate modified into combined with a hydrochloric acid provider solution and then reduced through sodium tetrahydridoborate which were stabilized with sodium hydroxide. The ensuing unstable hydrogen selenide modified into transferred with argon carrier gasoline into a heated quartz cellular established on an atomic absorption spectrophotometer for decomposition and size (Raymond and Ralston, 2020).

6.11.3. Statistics

Information was analyzed the usage of the SAS/SYSAT. previous to statistical assessment the records have been tested for normality and homogeneity of variance using the Shapiro-Wilkes statistic. Water statistics have become not commonly distributed and had been consequently log-converted. Invertebrate, sediment, and fish statistics met the assumptions of the model and were no longer transformed. versions among important results (fork; web site; habitat type) were analyzed the usage of analysis of variance (ANOVA) using the overall Linear models gadget. Relationships among matrices (fish, invertebrates, sediment, and water) were analyzed using bivariate correlation. Statistical significance modified into judged at the $p \leq 0.05°$.

6.11.4. First-Rate Control

The levels of concentrations were all much less than the method detection limits (1 µg/L for water; 0.2 µg/g dry wgt for sediments). Spike recoveries of Se averaged 97% for water (n = 24) and 98% for sediment (n=11). Recoveries of Se from reference answers averaged 100% for water (n = 64) and 98% for sediment (n=eleven). Relative percentage variations for copy pattern analyzes averaged 12% for water and 10% for sediment. top notch manipulates for all biota samples included digestion blanks, reference tissues, duplicates, replicates, pre-digestion spikes, and submit-digestion spikes. All digestion blanks exhibited selenium concentrations much less than the technique detection limits. assessment of four reference tissue substances brought about selenium recoveries starting from 100% to 107%.

Duplicates ranged from 1.2 to 26% relative percent difference (RPD) and averaged 9% RPD. The percent relative popular deviation (%RSD) from the triplicate steering and assessment of biota samples (replicates), ranged from 0.3 to 5.9% and averaged 2.4% RSD. Recoveries from pre-digestion tissue spikes ranged from 97% to 106% and averaged 100%. positioned up-digestion (evaluation) spikes, used to test for suppression or enhancement of the selenium sign on the tool, ranged from 92% to 110% recuperation and averaged 108%. The biota approach detection restricts several with each analytical run and ranged from 0.03 to 0.17 µg/g. All amazing manage consequences have been interior desirable limits for the styles of samples and analyzes involved.

6.12. CONCLUSION

Water in the Solomon River, just like the Republican River to the north, is a lotic gadget characterized as having shallow tributaries and essential forks with flowing water and clearly no deep swimming pools, ensuing in a bottom composed in huge part of sand, gravel, and strong rock. The primary supply of selenium is from cretaceous marine shales which underlie and floor outcrop into the Solomon River Basin (Sabuda et al., 2020).

Those shales encompass selenium frequently because the soluble oxyanion selenate (SeO_{24}), this is quite cell and without problems leached from soils by using irrigation pass returned flows or through touch of floor water with shale outcroppings. As soon as in floor water, lifestyles, and preservation of the SeO_{24} form is augmented via the shallow oxygenated nature of the tributary-river gadget. Concentrations of selenium in water from each collection net web page are furnished in desk three. Selenium in water

averaged 6.75 ± 5.56 µg/L selenium (n = 81) over the complete Solomon River Basin dataset. Over all habitat sorts and dates, selenium concentrations in North Fork water averaged 9.22 ± 6.17 µg/L selenium (n = 45) and were considerably more (one-manner ANOVA; p ≤ 0.001) than concentrations within the South Fork which averaged 3.34 ± 1.85 µg/L (n = 36). Selenium water concentrations in the mainstem of the North Fork averaged 9.08 ± 4.69 µg/L (n=12) and had been notably greater than concentrations inside the South Fork mainstem (common 3.34 ± 1.33 µg/L; n= 12). A-way ANOVA of selenium in tributary water found out an impact of (p = 0.0039) in North Fork and (p = 0.03111) in South Fork, with highest levels averaged in both regions during the late summer months. However, there had been no sizeable variations among the mainstem web sites (common 9.08 ± 4.69 µg/L; n = 12) and tributary web sites (commonplace 9.05 ± 6.46 µg/L; n = 26) of the North Fork (Figure 6.13) (Singh et al., 2015).

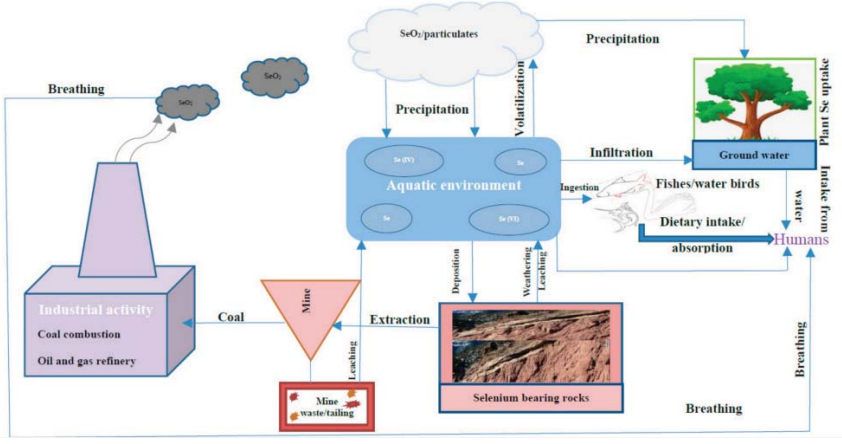

Figure 6.13. Environmental impacts of selenium contamination: A review on current-issues and remediation strategies in an aqueous system.

Source: https://www.mdpi.com/2073-4441/13/11/1473/htm.

In addition, there have been no large versions among mainstem web sites (3.34 ± 1.33 µg/L; n=12) and tributary internet websites (commonplace 3.17 ± 1.47 µg/L; n=14) of the South Fork. because of excessive drought conditions simplest a minimal wide variety of irrigation drain internet sites (n = 5 total) is probably sampled for water. highest observed concentrations came about at web site 7 (KWD) in which selenium averaged 20.75 ± 0.07 µg/L across sampling dates. This recognition was appreciably higher (p ≤

0.001) than selenium in water at the North Fork web site 17 (IDN; endorse 3.15 ± 0.22 μg/L). In assessment, ordinary concentrations of selenium within the South Fork were a great deal decrease than in the North Fork and sundry extensively with the aid of manner of internet page [site 36 (IDA) averaged 4.30 ± 0.28 μg/L; and site 34 (WB) averaged 3.10 ± 0.42 μg/L].

Simplest one sample changed into taken at the South Fork web website 43 (NDO-1; 0.10 μg/L selenium) which turned into the lowest selenium awareness in water located during the examine. reservoirs, Kerwin (North Fork) and Webster (South Fork), have been sampled in may additionally moreover, August, and September. Selenium concentrations in reservoirs did now not variety considerably and averaged 6.1 ± 1.2 μg/L (n = 3) in Kerwin Reservoir and 5.3 ± 4.7 μg/L in Webster Reservoir (n = 3). Samples from 85% of the websites in which water became present (n = 69) exhibited selenium concentrations that exceeded the water TET of 2 μg/L for one or extra series periods. in addition to the posted water TET fee, Lemly has additionally pronounced a hazard profile for selenium accumulation from water into the planktonic meals chain, with resultant toxicity to fish and aquatic birds.

CHAPTER 7

ENVIRONMENTAL CHEMISTRY OF SELENIUM

CONTENTS

Selenium is known to be an essential trace element for both human beings and animals but can be very toxic when they are at elevated levels. This compound is not known to be essential for plants. For the case of animals, the compound is a component of glutathione peroxidase (GPx) and helps in detoxifying a number of compounds such as superoxide, peroxides, and hydroxide free radicles and thus preventing any form of damage that may occur to the tissue especially cell membranes. Ideally, selenium complements the functions of vitamin E. though not well established, selenium might possibly have a number of other functions including the fact that it participates in the mitochondrion electron transportation system in the muscles. Deficiency of this compound causes the ill-thrift disease or the white muscle when it is more severe. It is more common in calves and lambs in the areas of Sacramento valley, northern Coast Ranges and San Joaquin valley, in California. Such problems are mostly associated with forages that are low in selenium due to the fact that they are cultivated in acidic soils that have high levels of free iron oxides (Figure 7.1) (Singh et al., 2021).

Figure 7.1. Selenium deficiency in cattle is common unlike the case of selenium toxicity.

Source: Agric Wa Gov Au.

7.1. GEOCHEMISTRY

Within the vicinity of power generating plants and coal-fired industries, atmospheric deposition of selenium is known to be significant in some soil-plant systems. Selenium content in most areas is normally dependent on the parent rock present at the area and the amount of rainfall. With low rainfall

levels and higher parent rock content, it is expected that the selenium levels are higher on the soil that has been forms. Rocks described as magmatic are known to have low levels of selenium content. On the other hand, sedimentary rocks are known to be rich in selenium but shales are richest in selenium contents. The average soil concentrating of selenium in the world is 400 ppb. However, in areas such as the great plains of the United States where selenium that is present in forage has caused toxicity for the domestic plants soils range from 600 to 28,000 ppb in selenium. Cretaceous-age Pierre Shale is where the soils from this region are derived from which are alkaline in nature and has a semi-arid form of climate. When soils are rich in selenium, then it is definite that the soil is high in alkaline content. In Ireland and Wales, selenium has leached to an extent that it has been able to affect the rich lands of Avonian shales, which are characterized as low-lying and organic and has led to the region containing 30,000 to 300,000 ppb of selenium (Figure 7.2).

Figure 7.2. In Ireland and Wales, selenium has leached and been able to affect the rich lands of the Avonian shales.

Source: TripSavvy.

On the western side of San Joaquin valley, the shallow ground water is known to be rich in selenium, which was received from the cretaceous-age shale formation on coast range, which is found on the eastern side of the vicinity. A hypothesis from a geological survey conducted by one Dr. Ivan Barnes concluded that the sediments were able to acquire their selenium when they were depositing as seleno-sulfides of iron. Consequently, the sediments uplifted and were exposed to oxidative conditions and the selenium released in the forms of selenite and selenite salts. On the other

hand, the sulfur appeared as sulfates. Later on, these materials eroded to from fans but the fact that the region experiences low rainfall, there was evapoconcetration of the salts at the rim of the Joaquin valley. In the process, it led to the inefficient transfer to the San Joaquin River, which then led to the ocean delta.

7.2. AQUATIC CHEMISTRY

In the world, Fresh, and marine waters are known to be 0.2 and 0.1 ppb rich in selenium, respectively, despite the fact that tiers in seepage water in regions of seleniferous soil which are known to be high in selenium are to 3 orders of value extra than the above stated values. The endorsed restriction in water for home intake is 10 ppb of selenium. This is because of the fat that, selenium is not considered to be a threat to both animals and humans at certain levels but are very toxic in some amounts. In smaller amounts, selenium is beneficial to both animals and human beings. The selenium amount prescribed for the town water as delivered to Davis, California regularly is known to either equal or exceed this value. A recent survey done through the U.S. Geological Survey of shallow wells and subsurface agricultural drainage waters at the west facet of the San Joaquin Valley has shown rather low or mild selenium tiers, which is, much less than 10 ppb in samples from the place round and to the north of Kesterson Reservoir. In contrast, samples from areas to the south, within the place of the Panache Creek fan in the Westlands district have ranged into the loads of parts according to billion. The maximum value is said to be over 4,000 ppb according to the sample from the water (Figure 7.3) (Song et al., 2021).

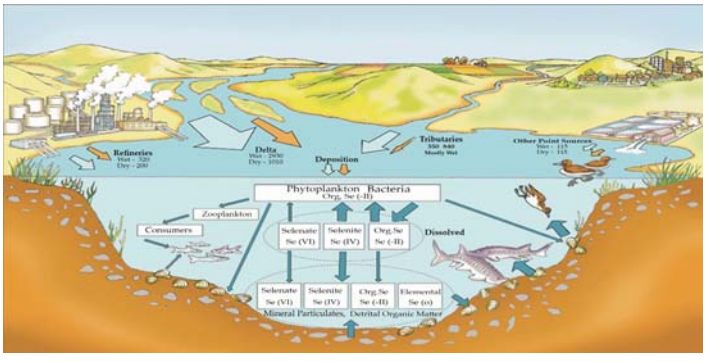

Figure 7.3. The accumulation of selenium in the water and soils.

Source: Tetra Tech R&D.

The high selenium waters were later on brought to the surface and drained to the Kesterson Reservoir in which at the point the selenium was taken up by the aquatic biota, which included the marsh plants, zooplankton, insects that form the diets of most animals in the region and phytoplankton. The selenium that is ingested by both the aquatic and terrestrial photosynthetic organisms are then transformed to organic or carbon-linked selenium in a biochemical manner. This normally takes place in selenoanalogs of sulfur, which are known to contain amino acids such as seleno-methionine, seleno-cysteine, and seleno-cysteine. Ideally, the higher life forms are known to take up these forms or higher forms of peptide or protein selenium in their diets into their tissues, which are effectively taken up inorganic forms including the selenite or selenite soils. According to a study conducted by the US Fish and Wildlife Services, the food chain transfer process has been able to bring about toxicity of selenium in aquatic birds of the Kesterson area. It is normally expressed in a number of ways including hatchling deformity, death, and toxicity symptoms in the adult fowl. There is little to no doubt that selenium toxicity in one form or another is the major cause of these problems associated to aquatic animals.

7.3. GEOBIOCHEMISTRY

As formerly noted, selenium deficiency in cattle is quite common in the California regions. It is frequently said within the literature that, livestock that is domesticated are known to experience, selenium deficiency across the globe unlike with the case of selenium toxicity. It has even proven to be something livestock rearers worry about because of the sickness the livestock may fall to because of the cases of deficiency. Selenium deficiency in human beings because of nutritional insufficiency is a pretty rare occurrence, despite the fact that youngsters have died in China in regions affected by "Keshan disease (KD)," which is thought to be because of cases of selenium deficiency. There is an extensive, global literature on nutritional stages in domestic animals such as sheep, cows, horses, and chickens that deliver upward thrust to signs and symptoms of toxicity in addition to deficiency. Deficiency is probable if the selenium attention in meals is much less, than 50 ppb selenium sufficiency is probable within the variety of 100 to 1,000 ppb. However, the toxicity threshold is from 3,000 to 5,000 ppb when in comparison with the literature on selenium reaction in wild animals, which is quite sparse (Figure 7.4).

Figure 7.4. Plants are also rich in selenium and they uptake them from their roots to form selenite and selenite ions.

Source: Medindia.

Plants are known to intake selenium from water present in the soil through their roots in the forms of selenite or selenite ionic forms. The quantities of selenium in the soils are dependent on the solubility of adsorbed forms and biological transformation of the organic forms. An approximate of 25 genera of plants are known to be selenium accumulators which include milkvetch, rattle weed, locoweed, prince's plume and Haplopappus genre which are known to have extraordinary abilities to acquire selenium which are known to be higher than other plants that are growing in the same soils. These plants are known to produce disagreeable odors which male them quite important in causing toxicity except in the case where plants are in severe starvation and are forced to intake these plants. In most instances, cases of selenium toxicity in animals are caused by the consumption of ordinary forages and the feeds that are grown in seleniferous soils. The selenium levels in plants are closely related to the levels that are present in the soil and are highly affected by the soil pH and temperature. Grains and seeds are known to be having high concentration of selenium even though there are cases where selenium levels are the same throughout the plan such as in the case of maize (Hernández et al., 2019).

For the case of human beings, high levels of selenium which causes toxicity is quite rare. Majority of individuals especially in the United States are known to consume 170 microorganisms with selenium per day from all

sources of food, which falls within the recommended selenium consumption levels. It is important to understand that there are those levels of selenium in water and food that are recommended for higher organisms and are not toxic. As such, there are some effects of selenium on the environment and human beings as described below.

7.4. HEALTH BENEFITS OF SELENIUM

This mineral is less heard of and is very vital human health. It is regarded as a mineral which means it has to be obtained through the diet. It is to be taken in very small amounts but it plays a very major role in the human body, i.e., body processes and the thyroid function. Selenium has been known to have health benefits to the human body. Although it is a vital nutrient, it has to be taken with meals and be taken in very small quantities (Figure 7.5).

Figure 7.5. Selenium is a vital nutrient and needs to be ingested, though in small quantities.

Source: Medindia.

The benefits of selenium include; it acts as a powerful antioxidant. Antioxidants are compounds found in food that help in the prevention of cell damage that may have been caused by free radicals in the body. The body on a daily basis forms free radicals during metabolism. The free radicals are very important in the body as they protect the body from diseases. In the human body when an individual smoke, drinks alcohol or an individual has stress can all lead to excesses of free radicals in the body. When the radicals are in excess in the body, they cause oxidative stress. The oxidative stress leads to

damage of the healthy cells in the body. The oxidative stress has also been linked to some chronic conditions such as heart disease, Alzheimer's and some cancer others include premature aging and risk of getting a stroke. The selenium helps in the reduction of oxidative stress by keeping the radical cells in the body in check. The selenium acts by neutralizing the excess free radicals and protection of cells from damage.

They reduce the risk of getting certain types of cancers. Selenium helps in reducing the risk of getting certain types of cancer. Selenium has been attributed to the ability of reducing DNA damage, oxidative stress, boosting of the immune system and destruction of some cancer cells. Studies have shown that having high levels of selenium in the body is associated with having low risk of contracting certain types of cancer such as breast, colon, lung, or prostate cancer. This was associated with selenium that was obtained with food rather than from supplements (Ali et al., 2021).

Protects humans against heart disease, low levels of selenium in the body have been linked with risks of getting heart disease. Recent studies show that individuals with low selenium levels have been linked to a high risk of getting heart disease. Selenium is known to lower markers of inflammation in the body, which is the main risk factors for heart disease.

It has been known to decrease mental decline. Alzheimer's disease is a devastating condition that causes memory loss and it also affects thinking and behavior negatively. In the United States Alzheimer's disease is the sixth leading cause of death. Individuals getting the disease has been growing. Oxidative stress has been known to be involved on the onset and progression of the disease. Individuals with Alzheimer's disease have been known to have very low levels of selenium in blood. For patients that had mild cognitive impairment, when they took the Brazil nut which is rich in selenium showed that there was improved verbal fluency and other mental functions.

It is important in thyroid health. Selenium is important in the proper functioning of the thyroid gland. Thyroid tissues are known to have high amounts of selenium than any other body tissue. The mineral helps the thyroid gland from oxidative damage and it plays a role in the production of thyroid hormone. The thyroid gland is very essential to the human body as it control metabolism and growth and development. When selenium is deficient, it has been known to cause Hashmoto's thyroiditis, which is a type of hypothyroidism, which causes the immune system to attack the thyroid gland.

It has been known to boost the immune system. Selenium has been known to boost the immune system. Individuals with less selenium in their body shows that they have low immune response. It has been seen that the people with selenium deficiency there is increased risk of death and disease progression for people living with HIV.

It has also been known to reduce asthma symptoms. When an individual has asthma, the airway becomes inflated and begin to narrow, then the individual has various symptoms such as shortness of breath, chest tightness, wheezing, and coughing. The selenium has been known to reduce inflammation.

Selenium is useful when taken by mouth and in small amounts. When an individual takes more than 400 mcg, it can lead to selenium toxicity. An individual can also take small doses for an extended period of time and this can increase the risk of developing diabetes. Several side effects of selenium include; muscle tenderness, blood clotting problems, liver, and kidney problems, facial flushing, lightheadedness, and tremors. When an individual consumes high doses of selenium, they have side effects such as loss of energy, irritability, nail changes, vomiting, and nausea. It causes poisoning especially when there is long-term use and it is similar to arsenic poisoning (Cooper, 2021).

7.5. EFFECTS OF SELENIUM ON THE ENVIRONMENT

Selenium in the environment occurs mostly from withered rock. It will then be taken up by plants, end up in the soil or even carried away by water. Selenium mostly gets into the air through combustion of coal or oil combustion as selenium oxide (Figure 7.6).

Figure 7.6. Combustion of coal leads to selenium mixing with air to form selenium oxide.

Source: Shutterstock.

This substance will then be converted to selenium acid through water or sweat. Although it can be converted to acid, it is mostly broken down to selenium and water, which is mostly harmless to the health of living organisms. The behavior of selenium in the environment will be dependent on its interactions with other elements in the environment. The environmental conditions will also determine its behavior. Evidence shows that selenium accumulates in body tissues of organisms and it can then be passed up the food chain. Biomagnification of selenium usually starts when organisms feed on plants that contain a lot of selenium. Research shows that aquatic organisms tend to have a lot of selenium in their body. Scientists believe that when organisms feed on plants or take up a lot of selenium then it will probably cause reproductive failure and birth defects.

When organisms such as fish are exposed to selenium in combination with low temperatures cased reduction in activity and there was less feeding, this resulted in 50–80% of lipids reduction in the body. After a few days quite a large number of fish die (Banuelos et al., 2002).

Figure 7.7. Forest activity is a natural occurrence that increases selenium in the soil.

Source; Daily Sabah.

When selenium is taken up by plants in low amounts it is helpful to the plants as it protects the plants from abiotic stresses such as metal stress, desiccation, cold, and drought. Selenium will occur in soil based on the type of soil and the area it is found in mountainous countries such as Finland, Sweden, and Scotland do not have selenium in the soil. Whereas in areas that have shale soils and dry have soils that are selenium rich such as the Punjab region in India, Japan, Greenland, and Venezuela. Selenium found in

water should not go above 10 ug/L. underground water has seen an increase in selenium levels because farmers are using fertilizers containing selenium. Anthropogenic and natural activities are increasing selenium levels in the atmosphere, i.e., the natural activities include forest fires and soil erosion while anthropogenic activities include burning of tires, fossil fuels and burning of paper (Figure 7.7).

Fruits generally have low amounts of selenium whereas cereals also contain some selenium as well as milk and other dairy products. Brazil nuts and garlic are some plants that contain a substantial amount of selenium.

When selenium becomes highly concentrated in plants it is referred to as selenosis or selenium toxicity. Selenium causes two types of mechanisms, i.e., malformed selenoproteins and induction of oxidative stress. When the plant has malformed selenoproteins, it is formed through disincorporation of SeCys/SeMet of Cys/Met in the protein chain. When this occurs, it alters the protein structure and this affects how it will function. At high doses, selenium will act as a pro-oxidant and it then generates reactive oxygen species (ROS), which in turn causes oxidative stress in plants.

When selenium is present in alkaline soils and eventually becomes oxidized as selenite, which is then water-soluble. This form of selenium is highly toxic as well as it is easily leached from the soil ad it is readily available for plants. On the other hand, in acidic soils the selenium occurs as a trace element or as selenide, which means it is bound to other metals, although it is still toxic but this form of selenium is not readily available for plants. Scientists believe that the concentration of selenium in soils will not directly determine the selenium concentration of the plants that are grown in that soil (Bailey, 2017).

In summary selenium is vital to plants animals and to human beings. When consumed or taken up in small quantities they are very crucial and very helpful. They are used for various metabolic processes. They have been known to occur naturally in the environment hence it is important to prevent accumulation of the mineral in order to prevent it from being transmitted up the food chain.

CHAPTER 8

TOXICOLOGY PROFILE FOR SELENIUM

CONTENTS

8.1. INTRODUCTION

Among the naturally occurring materials on the earth's surface is selenium. This solid substance is found in different areas of the world. Some researchers say that selenium distribution is uneven. This solid substance is known to occur in soil and rocks. There are different forms of selenium. It can be pure or impure. In its pure form selenium is can be black or gray. It is usually in its crystal form. While in this form, the selenium metal is called selenium dust or elemental selenium. It is quite difficult to commercially produce selenium in its natural form. Most of the commercially sold selenium is produced commercially as a by-product the coper refining process. The naturally occurring form of selenium is in its elemental form. In this form, the selenium rock has combined with other substances. For this reason, the selenium rock is said to be a combination of the rock with other naturally occurring materials such as nickel, lead, copper, and silver. In some cases, selenium crystal could be formed as a result of the combination of the metal with oxygen resulting in the formation of a crystal that is colorless or white in color. In other instances, the selenium compounds are in gaseous form (Figure 8.1).

Figure 8.1. The toxicology profile of selenium looks at its effects, uses, and potentials of being spread.

Source: http://www.samburcher.com/newsite/index.php/articles/public-health/13-selenium-conquers-aids.

There are various uses of selenium as a rock or by product of copper among them being them used in gun bluing, anti-dandruff, photographic devices, paints, plastics, fungicides, vitamins, and mineral supplements

and glass. When making products, selenium is used in different forms. For instance, when making anti-dandruff shampoos, selenium sulfide is used. Under livestock management, selenium is used in the preparation of nutritional feeds and drugs in supplementing poultry. Livestock can also acquire selenium naturally from environmental components (Buchs et al., 2013).

It is important to note that selenium cannot be created through artificial means. The rock occurs naturally and cannot be destroyed. However, the naturally occurring rock can be changed to different forms. Presence of selenium in water may be as a result of weathering rocks or siltation of soil containing certain amounts of selenium. The few amounts of selenium are taken up by plants. Selenium can also be present in the air in the form of dust particles. The dust particles find their way in the atmosphere through rock weathering processes. Another way in which selenium finds its way to the atmosphere is through volcanic eruption. Most fossil fuels contain a certain amount of selenium in them. When burnt, selenium present in them combines with oxygen. If selenium combined with oxygen is mixed in fresh water, the two react resulting in the formation of soluble selenium compounds. Particles of selenium in the air can be deposited in various surfaces. High levels of selenium in soil could be as a result of copper refining by-products being disposed of. It could also be as a result of commercial products containing selenium being deposited in waste lands or soil (Figure 8.2).

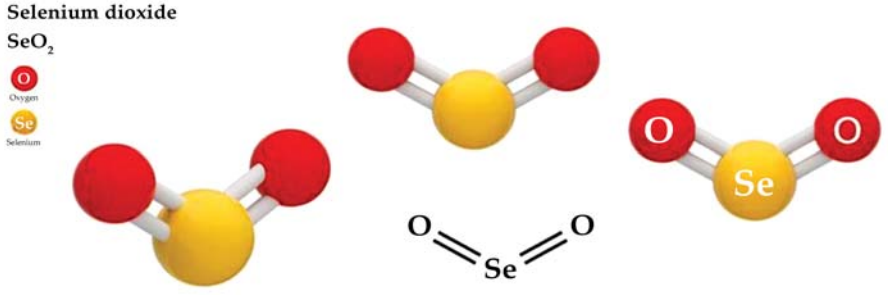

Figure 8.2. Selenium has a great affinity to oxygen.

Source: https://www.chemistryworld.com/podcasts/selenium-dioxide/7954.article.

The nature of selenium inn soil is dependent on a number of factors among them being the pH of soil and its reaction with oxygen. Soil is highly acidic if there are less amounts of oxygen in them. This means that the

amount of selenium taken up by plants is relatively low. In cases above, we have considered a form of selenium that is soluble in water. There are other forms of selenium that are not soluble in water. Among them is Elemental selenium and other forms of insoluble selenium can easily be identified as they can be attributed to certain characteristics among them being low mobility levels and are less likely to be exposed to human beings as they tend to live in the soil. There are various ways in which human beings are exposed to selenium. Among then being selenium entering drainage facilities or surface water used in irrigation. Increase levels of selenium in food chains are usually as a result of high-level uptake by aquatic organisms. Contaminated organisms usually find their way to the food chain resulting in selenium entering bodies of human beings and animals.

8.2. SELENIUM IN HUMAN BODIES

The main method in which selenium finds its way to the bodies of human beings is through ingestion of food containing selenium. Once ingested, it is very easy for the body to absorb selenium compounds. The body is also able to make use of the selenium components when needed. Water contains certain amounts of selenium in inorganic forms. Sodium selenite and sodium selenite are among the major forms of selenium in water. In inorganic form, selenium can easily be absorbed in the body. In some cases, the body modifies selenium to a form that can well be used by the body. Another way in which selenium finds its way to the body is through breathing of air having selenium components. High amounts of selenium find its way to the body through exposure hazardous waste sites. Usually, high selenium contents found in these sites make their way to the body when vegetables are planted in those areas. Also, if water supplies passing through these lands find their way to the main water supply or if there are strong winds resulting in selenium components being blown in the air. Under certain conditions, selenium forms can be modified. For instance, during high temperatures, selenium is able to react with other metals and oxygen resulting in the formation of other selenium compounds. Environmental conditions also determine the rate in which human beings are exposed to selenium compounds. Currently, there are concerns about selenium exposure among human beings and animals. This has resulted in governments opting to test water, air, and grown food to reduce chances of an exposure occurring. The benefit of selenium being used in making products such as shampoos is the fact that the selenium compounds are not easily absorbed in the body. Selenium is able to enter and leave the body within 48 hours (Bini, 2009).

Selenium is excreted from the body through breath, feces, and urine. Selenium levels in human beings should be relatively low. However, if human beings are exposed continuously then selenium levels will be high. In certain forms, selenium levels can soar up to exceedingly high amounts. Buildup of selenium in the body usually occurs in the kidneys, liver, testes blood, lungs, and heart. Depending on the duration of exposure, selenium build up can also occur in hair and nails.

8.3. EXPOSURE

There are three main ways in which human beings and animals can be exposed to selenium. These exposure routes are in fact ways in which selenium enters the body. There are namely: oral, dermal, and inhalation. With oral exposure, selenium enters the body through drinking water or food containing selenium elements. Inhalation is when an individual inhales air having selenium components while dermal is when one's skin comes to contact with selenium (Figure 8.3).

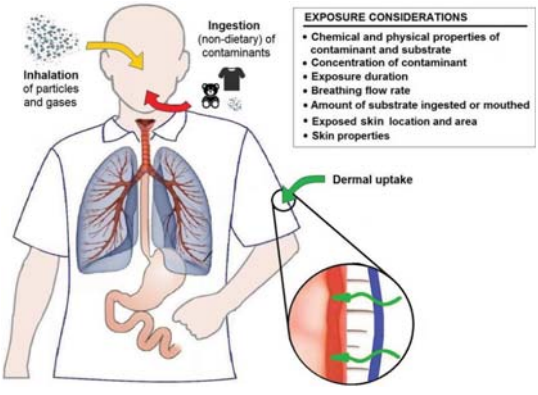

Figure 8.3. Depending on the exposure route, selenium can be chronically consumed.

Source: https://www.researchgate.net/figure/Non-dietary-routes-of-human-exposure-for-contaminants-of-concern-Inhalation-ingestion_fig1_332760303.

8.4. TOXICITY OF SELENIUM ON HUMAN

The level of toxicity of selenium is usually linked to the level of damage or threat posed on the lives of human beings. Some of the effects of selenium

on human health can be very catastrophic. Some of the effects are as given in subsections.

8.4.1. Selenosis

For this condition to occur, the individuals have to be exposed to high amounts of selenium over a long period of time. For this reason, the disease is said to be as a result of chronic exposure to selenium and its compounds through oral means. Symptoms are exhibited in two main forms. The conditions are usually identified in clinics as effects of selenium are neurological or dermal. This can be proven by numerous studies done on endemic Selenosis. M epidemiological studies of these illnesses have been done in China. Dermal effects of selenium on human health are exhibited by loss of nails, loss of hair, discoloration, deformation, and sever cases of tooth decay.

Figs. 1- 6: Clinical sign of chronic selenosis of dairy animals

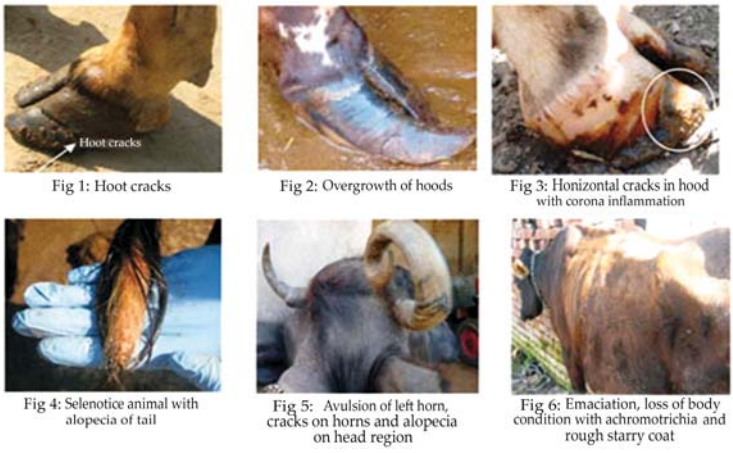

Fig 1: Hoot cracks

Fig 2: Overgrowth of hoods

Fig 3: Honizontal cracks in hood with corona inflammation

Fig 4: Selenotice animal with alopecia of tail

Fig 5: Avulsion of left horn, cracks on horns and alopecia on head region

Fig 6: Emaciation, loss of body condition with achromotrichia and rough starry coat

Figure 8.4. There are various ways selenosis manifests in human beings and animals.

Source: https://go.gale.com/ps/i.do?id=GALE%7CA470159687&sid=google Scholar&v=2.1&it=r&linkaccess=fulltext&issn=09721738&p=AONE&sw=w &userGroupName=anon%7Edab3d29b.

Symptoms of neurological effects of selenium include frequent hemiplegia, numbness, and paralysis. For an individual to suffer from Selenosis, selenium intake would have to be 10–20 times higher than the average amount of selenium consumed in a day. Selenosis is exhibited in both human and animals. For instance, in pigs, long-term exposure to selenium

compounds resulting in cattle, horses, and pigs suffering from malformation and hair loss. Pigs feeding on seleniferous plants are likely to suffer from polimyelomalacia (Figure 8.4). A common symptom of swine suffering from selenium-induced neurological conditions is exhibiting of bilateral microscopic lesions in the spine. Presence of selenium in certain plants such as *Astragalus bisulcatus* is considered to be very potent and a threat to animal neurological processes. Long-term exposure to selenium compound in swine, sheep, and cattle is known to cause myocardial degradation. Further research is being done to establish whether consumption of crops having certain levels of selenium will result in cardiomyopathy. Cattle that have consumed large amounts of selenium compounds orally exhibit histopathology and neurological signs. This cannot be proved in a laboratory as the effects cannot be noted. This goes to show that when testing toxicity levels in mammals, it is advisable for researchers to use large mammals. This is because results gotten from small mammals many not be similar to those exhibited by human beings. This is referred to as toxic-kinetic difference. The differences are as a result of the difference in absorption rates exhibited by mammals of different sizes. Neurological effects of selenium in livestock and human beings in the form of chronic Selenosis is attributed to the consumption of unidentified organic forms of selenium (Domokos-Szabolcsy et al., 2018). Neurological syndromes linked to chronic Selenosis are determined by the amount of selenium present in the plant. If a plant contains high levels of selenium, then it is said to be highly toxic. Other factors affecting the likelihood of an individual suffering from Selenosis. This includes the presence of nutrients such as vitamin E and also xenobiotic such as methionine. Neurological manifestation of organic selenium is as a result of some unidentified forms of selenium. Presence of selenium in the human body is crucial as it is related to the working of various human hormones. In the deiodinase family, selenium is a major component of the three elements. Controlled thyroid hormone levels and deionization of thyroid hormones are maintained by deiodinase hormones. Increased amounts of selenium in diets are known to cause a decline in the level of serum T3 hormones. The same is exhibited in humans environmentally exposed to selenium. Biological changes are said to be undefined as there are normal ranges of T3 hormones observed in humans exposed to selenium. Though there are speculations of selenium affecting thyroid hormones. This has not been proved. However, increased amounts of selenium in the body of human beings are said to be related to the decline in type-I-deiodinase activity (Figure 8.5).

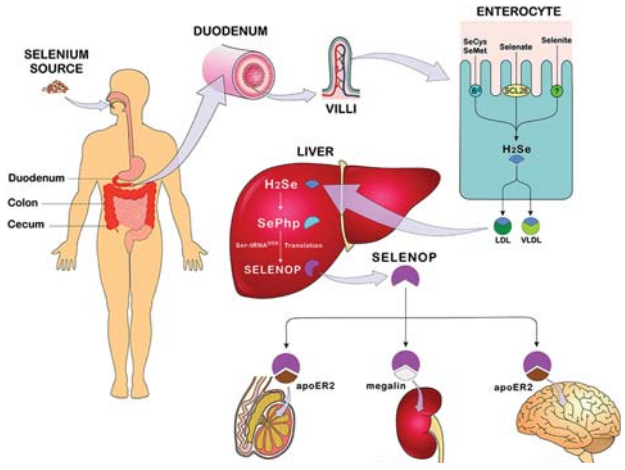

Figure 8.5. Long-term exposure to selenium results in dire effects.

Source: https://www.frontiersin.org/articles/10.3389/fnut.2021.685317/full.

Long-term oral consumption of inorganic and organic selenium is known to cause a decline in animal growth rates and weight loss. If selenium having endocrine or thyroid components are likely to cause a reduction in child growth. As mentioned earlier, there are certain body organs that can easily indicate the presence of selenium. This means that the likelihood of selenium causing toxicity in the pancreases is attributed to the likelihood of the elements accumulating in it.

8.5. REPRODUCTIVE EFFECTS

With regards to reproductive effects, there is little proof to show that increased selenium intake can cause reduced seminal fluid levels, sperm mobility and sperm count. Consumption of high levels of selenium through drinking water has not been linked to spontaneous abortion. This is the case in human beings. In animals, the case is different as increased selenium intake of sodium selenite and selenite in amounts higher than normal is said to cause abnormalities in sperm production, atrophy in male rats, degeneration, and testicular hypertrophy. Among females, increased consumption of selenium compounds is said to cause alterations of estrous cycles. Generally, consumption of selenium compounds in high amounts causes fertility issues. Animals given oral treatments using drugs such as L-Selenomethionine are said to suffer from alterations in their menstrual

cycles. This means that selenium affects follicular phases, short luteal and anovulation more so in monkeys. For rats, reduced consumption of selenium is said to cause reduced sperm motility and production. Effects of selenium in reproductive organs of human beings have not been established. However, effects of selenium on the reproductive health of animals have been established as several experiments have been done on various species of mammals. There are other negative effects of selenium on the health of human beings and animals resulting in its toxicological effects (Figure 8.6).

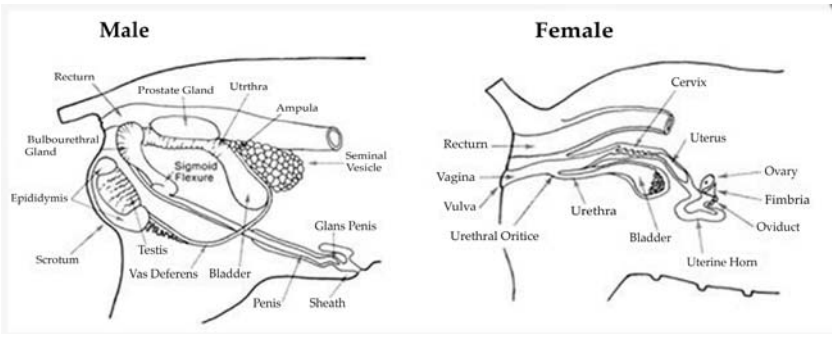

Figure 8.6. Large amounts of selenium in the body affect reproductive organs.

Source: https://www.minipiginfo.com/pig-anatomy-and-terminology.html.

8.6. TOXIC EFFECTS OF SELENIUM

Depending on the level of toxicity, there are sever effects of selenium on human and animal health. In most cases, they result in chronic illnesses. Among them is Chronic-duration cancer and exposure. Several studies have been done to examine the effects of chronic inhalation exposure. When individuals are chronically exposed to inhalation of inorganic selenium compounds they were said to suffer from primary respiratory issues. In some cases, individuals suffer from gastrointestinal, ocular, dermal, cardiovascular, hematological, neurological, and dermal effects. If the chronic exposure is through oral means, major effects noted in human beings were endocrine, dermal, and neurological. Among the chronic exposure methods is through the skin. This has resulted in dermal effects. For individuals consuming certain levels of selenium, it is crucial for them to eat highly nutritious foods. As it helps them develop an immune system able to reduce the effects of excessive consumption of selenium (Charya, 2017).

Genotoxicity is also an effect of chronic consumption of selenium. With Genotoxicity, both sister chromatid and chromosomal aberration modifications in the lymphocytes did not record an increment in treated humans. However, if the treatment was not properly controlled then oral consumption of selenium of selenite and selenite is said to increase the number of micronuclei in cells of the bone marrow. It was later discovered that exposure of cells to selenite and selenite results in both antigenotic and genotic effects. Reproductive toxicity is also another issue related to selenium consumption. Among small mammals, exposure to high amounts of selenium resulted in reproductive problems. For this reason, there are controlled amounts of selenium given to individuals on a daily basis. Excessive intake of selenium could result in low sperm count and motility. This is mostly evident among small mammals compared to human beings. Though increased selenium consumption could cause abortion, minimum cases are recorded among women who consumed water having selenium.

8.6.1. Death

The most sever effect of selenium exposure is the death of infected animals and human beings. Exposure to small amounts of selenium is not dangerous to human beings. However, if it is consumed in small amounts over long periods of time it is very dangerous as it could result in underlying conditions that could lead to death. This was noted in the study that involved pigs being exposed to selenium. Some pigs were exposed to selenium over a short period of time while others were exposed to selenium over a long period. In the experiment, 5-week-old pigs were involved in the experiment. They were eight in number and each pig was exposed to about 1.3 mg of selenium daily. The selenium dosages were given in form of sodium selenite for 10 days. By the end of one study, all of the pigs had died. In this study, only one level of the selenium dose was used. In another instance two long-tailed macaques were used. During the experiment, the animals were given 0.60 mg selenium in a day. Selenium was administered in the form of Selenomethionine through nasogastric intubation. The animals died due to aspirate or anorexia aspirated vomitus followed by gastritis. The death occurred 10–15 days after the onset of the treatment (Figure 8.7).

Figure 8.7. Exposure to high amounts of selenium in small mammals results in death.

Source: https://www.adirondackalmanac.com/2014/02/cabin-life-life-death-small-mammals.html.

The same case was exhibited in rats. In a certain study, 12 female rats were involved in the study. Each of the rats were given diets each containing 0.418 mg selenium in a day. It was administered in the form of sodium selenite. Within 14 days of the experiment, about seven of the 12 rats died. In the case of male rats, they were exposed selenium doses through exposure to water containing 0.84 mg selenium per day. The experiment ran for 4–6 weeks and resulted in the death of four out of the initial six rats. As the experiments were done on small mammals, it is anticipated that the results may not be similar to that of human beings and other big mammals. This is because absorption rates and effects will vary in among them. Therefore, death in large mammals is less likely to happen though it can happen as a result of underlying conditions brought about by consumption of selenium products (Déon et al., 2017).

8.7. REGULATIONS AND ADVISORIES

As there are various exposure routes, health effects and potential death in organisms, there are guidelines and regulations that have been developed to regulate the use of selenium in different countries. The laws are applicable in different state and national agencies. The Food and Nutrition Board (FNB) of the National Research Council established the currently used recommended dietary allowances (RDAs). The regulations have been made on the basis of

the amount of nutrient intake that could not pose as a threat to human beings. The highest level of nutrient intake on a daily basis that could not endanger the health of human beings is referred to as the UL. The regulations indicate the largest amount of selenium levels that can be consumed by different groups of individuals. For instance, the largest amount of selenium that can be consumed by women in a day is 0.055 mg selenium in a day. The same applies for males. About 0.060 mg is the highest for pregnant women, lactating women is 0.070 mg selenium, day infants 0.015 mg selenium, infants from 7–12 months is 0.020 mg selenium and varying amounts for children of different ages. For those in the age of 1–3 the highest level is 0.020 mg, 0.030 mg selenium for children from 4–8 and 0.040 mg selenium for children in the age of 9–18. This should be upheld by all relevant bodies dealing with food, water, and cosmetic production. The same also applies for the making of other products.

CHAPTER 9

ECONOMIC IMPACT OF SELENIUM

CONTENTS

9.1. INTRODUCTION

The world's limited selenium resources must be carefully controlled. Selenium is obtained as a by-product of copper mining, and no selenium resources can be exploited separately. Selenium is a semi-conductor with unique qualities that make it valuable to industry, but it is also a vital nutrient for animals and humans, and it may aid plant production and yield. For 0.5 to 1 billion individuals around the world, selenium shortage is a major health concern, and an even wider range may ingest less selenium than is necessary for maximum safety against malignancies, heart disease, and severe viral infections like HIV.

It is indeed challenging to recycle selenium effectively. Certain commercial fertilizers contain selenium, but plants only absorb a small fraction of it, and most of the rest is wasted for future use. Huge-scale bio-fortification programs including selenium into commercial fertilizers may thus be a costly fortification strategy that cannot be implemented to large parts of our planet. The food industry has the ability to add selenium elements directly to food (process fortification) (Figure 9.1).

Figure 9.1. The quantity of selenium in the plants that animals eat is affected by the selenium content of the soil, hence selenium levels in animal foods fluctuate. The level of selenium in soil, however, has a lower impact on selenium in animal products than in vegetables and fruits, as animals preserve the consistent tissue levels of selenium by homeostatic mechanisms. Furthermore, selenium levels in formulated livestock diets are often the same.

Source: https://www.indiumsoftware.com/blog/selenium-tools-advantages/.

However, oxidation associated with heat processes must be avoided if selenomethionine is added straight to food. New approaches to bio-fortify food items are required, and it has been discovered that adding selenium late in the production process rather than early reduces wastage. On these grounds, researchers suggest that selenium-enriched, sprouted cereal grain be added during food processing as a cost-effective strategy to supplement inadequate diets with this vitamin. Selenium is a finite resource that cannot be replenished. Large-scale mining and industrial processing are now responsible for massive selenium waste. Researchers believe this has to change, and that a large portion of the selenium recovered should be stored for subsequent generations to consume as a nutrient (El-Ramady et al., 2020).

Selenium (Se) is an uncommon mineral on our planet, having an estimated abundance of only 0.05 mg/kg in igneous bedrock, the lowest of any nutritional element. Because there are no ores from which Se may be mined as a principal product, the world's Se supply is limited. The amount of Se in food is determined by a number of geological, biogeochemical, and climate conditions. Selenium enters the food chain via plants, and crop Se concentrations vary depending on available soil Se concentrations, bioavailability for absorption into plant roots (which is influenced by redox equilibria in the soil, among other things), and plant species. The heterogeneity of Se distribution around the planet is depicted in a global atlas. Selenium is essential for the wellbeing of all living things. A large proportion of the world's population is thought to have inadequate Se intakes, putting them at risk for a variety of ailments including cancer, cardiovascular disease (CVD), viral infections, and other oxidative stress-related conditions.

There are numerous disease conditions (for example, hypertension, several viral infections, and possibly asthma) in which the sickness and increased oxidative stress are triggered by variables other than Se insufficiency per se, but where good Se status combined with adequate supply of other anti-oxidative vitamins and minerals may help tissues and organs cope better with detrimental oxidative stress. For both present and future generations, efforts to enhance Se concentration in the diet are critical. Selenium is also a critical component in high-tech uses, and the material is in high demand in business. To meet the demands of both health and industry, approaches to improve Se production and recycling, as well as constraints in consumption, may be required. It is time to talk about some strategies to make Se use more efficient in agriculture and food.

9.2. PRODUCTION OF SELENIUM

The majority of the world's Se is produced as a by-product of copper mining in the United States, Germany, Japan, Belgium, and Russia, with minor amounts coming from other nations like Canada, Australia, and China. Since the element was first employed commercially in the early 1900s, global output has risen dramatically. Global production peaked at 5,000 kg in 1910 and has since risen to an estimated 2,300 tons each year (Figure 9.2).

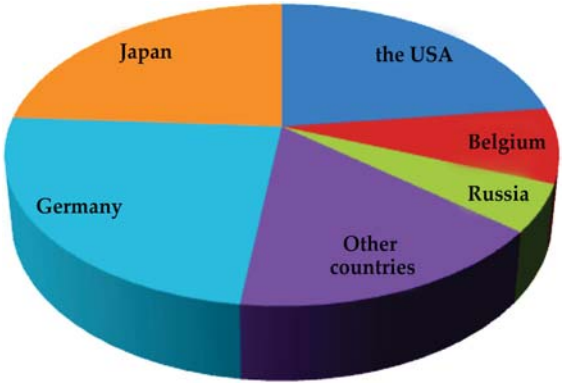

Figure 9.2. Selenium is a malleable metal that comes in a variety of allotropic forms. Selenium is a material that is both photoconductive and photovoltaic. Selenium's special qualities make it useful in the production of photocells, which turn sunlight into electrical energy. In total, only about a quarter of the selenium used each year is employed in various electrical applications. Glass, fertilizers, and vitamin supplements are some of the other key selenium applications.

Source: https://mcgroup.co.uk/news/20131122/global-selenium-supply-recorded-11-growth-2.html.

Selenium is a trace element that is important for human beings and all animals, along with being used in a variety of industries. Se's use in science and farming, where it is added to chemical fertilizers, livestock feed, veterinary treatments, and as a human dietary supplementation, accounts for just around 5% of overall demand, but it is predicted to grow significantly in the future. Industrial Se demand accounts for the most part of the production, and includes a wide array of industrial uses, like glass, pigment electronic, pigment, glass, metallurgy, and other uses of 35%, 10%, 30%, 10% and 10% of demand, respectively (Feng et al., 2021).

Selenium is valuable in industry because of its unusual electrical characteristics. When exposed to light, its electrical conductivity, which is

modest in the dark, increases hundreds of times. Selenium is a semiconductor that has an asymmetrical conductivity which makes it easier to drive electrical current in one trajectory than in another so it is important to reduce solar heat transmissions in several electrical devices. Selenium is also employed in the production of glass colors, pigments, and photoreceptors.

The availability of selenium is heavily reliant on the production of the main substance from which it is generated. Global selenium output is expected to increase in the next years, owing to the ever-increasing global copper market. In 2015, the amount reached an approximate 2,800 metric tons. Because there are few alternatives to selenium produced in this field, total demand for the commodity in the glass industry is expected to rise in the near future. In the meantime, demand for selenium from solar cell manufacturing is expected to decline in the future years.

9.3. REUSING AND STOCKPILING SELENIUM FOR THE FUTURE

Because Se is used as a small component in so many processes, efficient recycling is challenging (or unattainable), and only around 15% of refined Se comes from secondary sources. Selenium may be recovered affordably from commercial scrap and industrial process residues, and worn and broken photoreceptor drums, for instance, are reused. Several metals, including copper, are frequently reused. There is now a tremendous waste of Se associated with enormous mining and industrial processing when the Se concentration of sulfide ores and coal is not recovered (e.g., nickel, and coal). Hopefully, this will change in the near future, and we encourage the storage of the majority of the Se harvested for subsequent generations to use as a nutrient.

Because Se is essentially a by-product of copper filters, and there are no industrially exploitable resources for Se alone, we could therefore predict that correlating Se demand in the years ahead will be higher than for copper when copper is extremely easy to recycle, with a higher percentage of copper re-use than Se. As a result, selenium may be in short supply. Currently, the price of sodium selenate in Australia is comparatively low, with the price ranging between A$120 and $160 per kilogram (in early 2007), which may not enhance cost effective use (Figure 9.3).

Figure 9.3. Other methods for obtaining selenium include roasting using fluxes to transform selenium into its volatile oxide, which is subsequently collected from flue gas. Selenium can also be calcined into a soluble form that can be leached away. More than 80% of the world's selenium is manufactured at refineries in Belgium, Japan, Germany, Canada, and the United States. The selenium used in commercial products is 99.5% pure.

Source: https://www.news-medical.net/amp/health/Selenium-Production.aspx.

9.4. IMPROVING THE EFFICIENCY OF COSTS IN THE HEALTH SECTOR

Selenium is by far the most crucial mineral many have never heard of, and it could be our (losing) hidden weapon in the fight against cancer and other diseases. The good news is that cancer claims fewer lives now than it did 25 years ago. However, the number of cancer cases is rising, and all of those costly therapies are causing Big Pharma's checkbook to burst at the seams. In 2017, global cancer care spending was $133 billion (the latest year that stats are available). Furthermore, the list price of new cancer medicines continues to rise.

A new cancer treatment now costs more than $150,000 per year on average. When compared to $79,000 in 2013, this is a significant increase. It is no wonder that with so much money on the line, people are not hearing about low-cost, natural preventative procedures (Frankenberger et al., 2004).

However, there is one; it is called selenium, and it has a slew of advantages no one should overlook. This micronutrient is an important nutrient, which means it can only be acquired through ones eating habits. Despite the fact

that you should only require a minimal quantity of it, an approximated 15% of the globe's population is currently deficient in selenium. Numbness, weakness, exhaustion, and a sluggish memory are early warning indications of low selenium levels. As several studies have shown, continuing along this route greatly increases the incidence of prostate, lung, gastrointestinal, and colon cancer. According to a study published in the Journal of the American Medical Association, when this one element is properly ingested, the incidences of these cancers decline by 71%, 46%, 62%, and 67%, respectively. But selenium's importance is not limited to the battle against cancer.

This micronutrient safeguards your DNA like a superhero. It fights free radicals while preventing chromosomal damage. It is also a powerful antioxidant that helps the immune system. To function properly and be healthy, your thyroid needs adequate selenium levels. Your metabolism may become out of whack if you do not take it. Even worse, selenium deficiency has been linked to thyroid-related autoimmune diseases. Patients with mild cognitive impairment improved after eating selenium-rich Brazil nuts on a regular basis, according to a small research published in the European Journal of Nutrition (Figure 9.4).

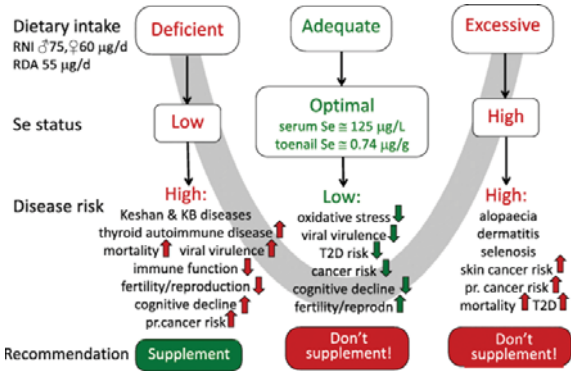

Figure 9.4. By study population, cumulative mortality from all causes throughout time. The Kaplan-Meier method was used to estimate non-parametric cumulative mortality curves (step functions), which were then compared to the findings of the generalized Wilcoxon test. A spline-orientated parametric survivorship of the treatment-specific log cumulative risk, parameterized as natural cubic log time spline with knots of the non-censored log-tempo distribution, has been estimated at multivariate cumulative mortality curves (smooth lines).

Source: https://link.springer.com/article/10.1007/s42000-019-00125-5.

There could potentially be a connection between selenium and Alzheimer's disease. Patients with this horrible disease have decreased amounts of selenium in their blood, according to several studies, implying that selenium could play a significant protective role. Selenium's work is never done when it comes to combating viruses and bacteria, boosting your immune system, preventing cancer, and maintaining healthy lungs and fertility. That is why you must ensure that you are getting enough.

Our food supply is deprived of nutrients, as has been noted before. Some fertilizers deplete selenium in the soil. Crop rotation procedures that are not followed are also to blame. Plants are not able to absorb elements that are not present in the soil, so if your food is not able to absorbing selenium, you are dealing with a selenium shortage. It is true that many foods contain trace levels of this vitamin. Selenium is abundant in lean meats, poultry, eggs, beans, and nuts. Brazil nuts get a lot of points.

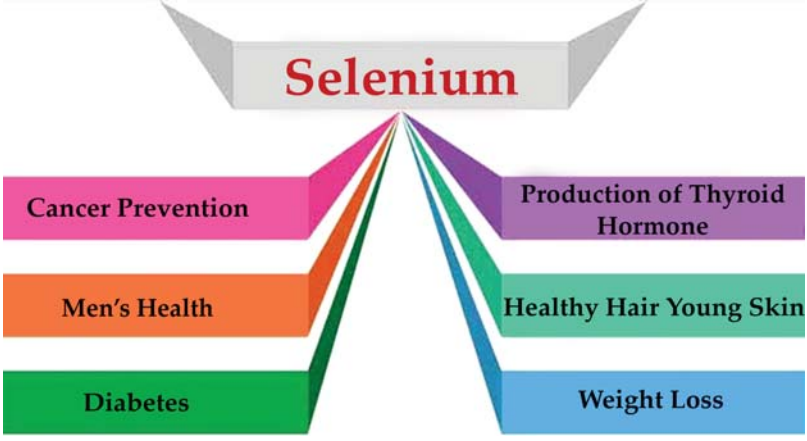

Figure 9.5. Overall, selenium is an essential trace mineral that provides a wide range of health benefits when ingested in sufficient amounts. Many people who are at risk for or already have chronic conditions including heart disease, thyroid disease, or cancer can benefit from selenium. If you feel you may be deficient in selenium or plan to begin selenium supplementation, you should always contact with a nutritionist.

Source: https://www.medindia.net/amp/patients/lifestyleandwellness/selenium-natural-source-better-than-supplements.htm.

The RDA for selenium is 55 micrograms per day for adults and children over the age of 14. However, this is not the ideal quantity. It is recommended

that you take 200 micrograms per day to gain the protective effects of this strong warrior. So, a few of Brazil nuts a day, along with a few oysters, should get you on the correct track. Supplements might also help to fill in the gaps. However, not all supplements are made equal. SelenoExcell, a type of selenium yeast, is used to make the most effective supplements (Figure 9.5).

This being said, Selenium can be utilized for the reduction of medical costs globally as well as reduce mortality and diseases. According to epidemiological findings, the selenium intake required to saturate the antioxidant capacity of blood plasma and to provide optimal protection against cardiovascular illnesses and cancer is higher than many people's average intakes. Se supplementation at a 'supra-nutritional' level has also been found to have substantial therapeutic potential against colon cancer, lung cancer, prostate cancer, and liver cancer in two prospective clinical investigations. Few communities have intakes that are close to this 'supra-nutritional' threshold, i.e., 200 g or more per day (Zhang, 2014).

As a result, low Se condition is predicted to lead to cancer and heart disease mortality and morbidity, while raising Se intakes may lower cancer rates and ischemic heart disease mortality. If total age-adjusted mortality from cancer and CVD could be reduced by more than 20%, as shown by spatial epidemiological studies contrasting states with lower and higher Se intakes in the United States, the health economic consequences would be tremendous. Even so, it is important to note that the world desperately needs significant cost-effectiveness improvements in the health services industry if the developed economies are to be able to address at the same time the challenge of adequate medical care for their older populations and finance the profound technological and economic restructurings needed to prevent a global climate catastrophe.

Increased human Se consumption can be accomplished in a variety of circumstances, including enhanced intake of higher-Se foods via the usages of Se fertilizers, elevated usage of plants that normally build up a lot of Se, growing seeds in Se-enriched media, plant genetics for improved Se accumulation, farming in Se-rich areas, livestock supplementation, fortified foods, and more.

9.5. THE GLOBAL BUDGET OF SELENIUM

The world's annual agriculture, fish, and seafood production is at an all-time high. Estimates of spontaneous fluctuation in Se concentration in various dietary products are also available. The world's yearly Se generation from

agriculture and fishery may be calculated by multiplying the projected Se concentrations by the annual amount of various food products produced. Cereal grains, trailed by fruits/vegetables, and roots/tubers, are the most major dietary sources of Se worldwide. The total Se intake from cereals is almost 10 times that of meat (Figure 9.6).

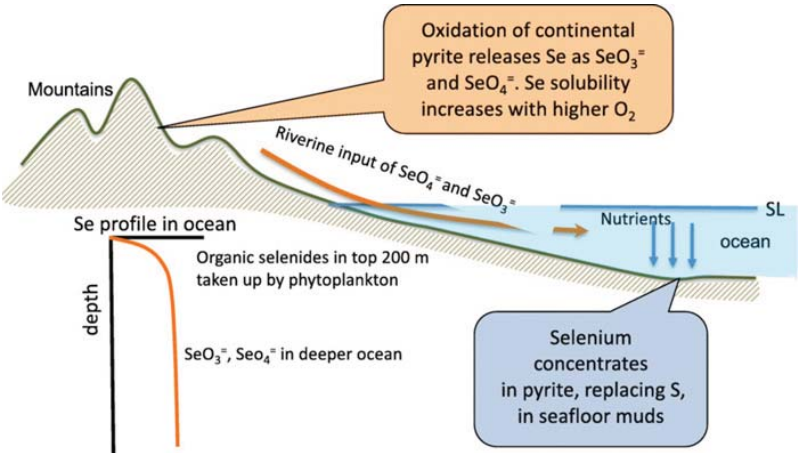

Figure 9.6. The selenium cycle is depicted as a model. Selenium is obtained by the erosion of sulfides, primarily pyrite, from continental rocks and is carried to the ocean as selenate and selenite complexes under an oxygen-rich environment. As a nutritional trace element, selenium is absorbed by organisms and eventually accumulates with organic matter on the bottom. Se is then absorbed into diagenetic pyrite, taking the place of S in the pyrite structure.

Source: https://www.researchgate.net/figure/Model-of-the-selenium-cycle-Selenium-is-sourced-from-erosion-of-sulfides-mainly-pyrite_fig9_331653572.

By summing the world's Se production from mining, agricultural goods, and fisheries, a Se budget may be created. Estimate of the annual Se necessity for the global livestock and global population, utilizing both the required dose of approximately 50 μg Se per day and a daily total of 100 μg per day and the recommendable daily amount to help prevent certain cancers, 250 μg Se per day, are calculated using a multiplication of world population with the suggested Se input.

The annual Se manufacturing process estimate is approximately 400 tons, via fisheries and agriculture. While this quantity of Se-if equally distributed-can be sufficient to provide 100 μg per day for every person and animal head in the world, the higher rate that can protect against cancer

is not sufficient. Since the pigs and poultry numbers are unreliable in this discussion, their requirements are not included. The requirement would actually be higher than this estimation, given that the intake is distributed unequally throughout the world. Regarding unequal distribution Combs has stated that roughly 500–1,000 million people must be supplemented to prevent Se deficiency, not to mention the vast majority of those deemed subclinically deficiency (Garousi et al., 2016).

Since the actual demand for optimal prevention and treatment of cancer and other illnesses is claimed to be higher than 0.05 mg/day (around 0.2 mg/day or more), Se production through farming and fisheries may be too small annually to satisfy human requirements, and Se supplementation may be required in numerous regions of the world. The globe's rare Se resources must be properly maintained to prevent this sensitive resource from being squandered. Selenium is necessary for human health, animal health, and the quality of animal products, and it may also aid plant development and quality. Major-scale bio-fortification programs involving the addition of Se to commercial fertilizers may be too wasteful to be applied to a large portion of our globe, as much of the Se used will be lost for future use (Figure 9.7).

Figure 9.7. The economic benefits of various kinds of goods and services, as well as growth opportunities, consumer patterns and downstream application field structure analysis, are all thoroughly examined. This keyword market study analyzes in detail the potential hazards and possibilities that may be focused on to increase growth throughout epidemic period.

Source: https://uk.metaconceptgroupe.com/selenium/.

Plant and animal products bio fortification must be carefully considered and caution must be exercised to prevent waste. Each country should assess these supplementing strategies in light of Se resource planning and sustainability. The food industry has the ability to add Se components directly to food (industrial fortification). Heat processing must be prevented if Se-met is added directly to food. It is an intriguing concept to add Se-enriched sprouts to food products, which are created by germination of seeds in Se-rich media. Supplementing the diets of populations in poor nations, where access to processed and fortified foods is restricted, requires special thought.

CHAPTER 10

SELENIUM REMOVAL IN WATER

CONTENTS

10.1. INTRODUCTION

Selenium is a water treatment contaminant that is common in sectors such as oil refinery, mining, and energy technology. It is well known that the presence of selenium in consumption water in higher concentrations has lethal impacts on both people and aquatic life. The highest level of 10 μg/L has been distinctive for selenium in consumption water through federal and provincial regulatory groups. Selenium finds great utility within the production of paint, glass, photocells, rectifiers, and insect repellent. Selenium concentration in commercial effluents may additionally range from 1 to 7,000 μg/L. This chapter reviews different Selenium Removal technologies like sedimentation, filtration, ion exchange, reverse osmosis, organic treatment and activated carbon adsorption (Figure 10.1) (Okonji et al., 2020).

Figure 10.1. Selenium removal laboratory in a secluded zone.

Source: https://www.wateronline.com/doc/selenium-removal-technologies-a-review-0001.

10.2. REMOVAL TECHNOLOGIES

Selenium is extracted from wastewater really through biological and chemical/physical procedures. This section will discuss these technologies, various technology providers, and other resources of importance.

10.2.1. Biological Treatment

As a natural component, selenium cannot be obliterated. The viability of physical, compound, and organic treatment alternatives is reliant upon the selenium state, which additionally influences portability and toxicity in the

surrounding. Organic treatment is promising on the grounds that it changes selenium over to a less poisonous structure. Both mechanical and regular treatment frameworks have been utilized to organically remove selenium in water. Natural treatment of selenium works by microbes utilizing selenate and selenite as electron acceptors. Broken up selenium is diminished to essential selenium, which becomes related with the microorganisms and can be eliminated from water utilizing gravity settling as well as filtration (Tanmoy et al., 2019).

Organic treatment of selenium gives an expense serious alternative to meet administrative requirements. While natural treatment is not possible for each undertaking, it has ended up being a valuable device in securing the environment while adjusting the expense of administrative treatment. Broken up selenium (selenite or selenate) can be naturally diminished by microorganisms under anoxic conditions to basic selenium, which is a pink-shaded metal. This cycle requires a carbon source to fill in as an electron contributor and a few hours pressure time, like organic denitrification. In the event that nitrate is additionally present in the water, it will normally be specially diminished before microscopic organisms lessen selenite/selenate. The ordinarily low centralizations of selenium to be taken out imply that lower dosages of carbon, including methanol or molasses, can be utilized contrasted with denitrification. Natural treatment measures generally require upstream treatment to eliminate solids, as well as downstream treatment to channel biomass, hastened selenium, and conceivably add broke up oxygen to meet release limits. One benefit of natural treatment is that both selenate (Se_6^+) and selenite (Se_4^+) are diminished to essential selenium.

Natural treatment frameworks, which are regularly appended development reactors using bacterial biofilm on a media surface, incorporate pressed bed reactors (PBRs), fluidized bed reactors (FBRs), moving bed organic reactors (MBBRs), and electro-biochemical reactors (EBRs). Appended development frameworks are most appropriate for developing adequate biomass to treat wastewater, which ordinarily contains low centralizations of selenium. The PBR is a downflow joined development framework. Filtration of suspended solids might be needed to forestall media stopping, and intermittent back flushing is expected to eliminate dead biomass. Average media are sand or granular enacted carbon (GAC). GE Water utilizes it is anything but, a PBR, to organically eliminate selenium with normally happening, non-pathogenic microorganisms. Nitrate can be taken out in a similar interaction. ABMet bioreactors use a permeable, high-surface region medium, normally GAC.

The FBR is an up flow appended development framework in which water goes through a granular strong medium at a sufficiently high speed to suspend the media. This gives greatest contact among toxins and the microscopic organisms connected to the medium. Commonplace media utilized are again GAC or sand. Envirogen Technologies, Inc. has planned a little impression FBR for selenium expulsion. The interaction purportedly creates emanating focuses under 5 ug/L, even within the sight of significant degrees of nitrate. Containerized FBR frameworks can be measured to treat a wide scope of streams (100 to 3,000 gpm) and influent water characteristics.

10.2.2. Chemical Treatment

These innovations incorporate oxidation/decrease, iron co-precipitation, particle trade (IX), and adsorption:

1. **Oxidation/Decrease:** Selenium species are seldom deliberately oxidized, as this may put them in the hard to-eliminate selenate state. Be that as it may, decreased species, for example, selenocyanate (normal in stripped acrid water in oil refining) expect oxidation to selenite or selenate for organic treatment to be compelling. A standard oxidant like chlorine, hydrogen peroxide, or potassium permanganate can be utilized. Decrease is every now and again refined through natural treatment or the accompanying compound treatment measures (Hasanuzzaman et al., 2020).
2. ***Iron Co-Precipitation:*** It is a cycle wherein encouraging generally a lot of ferric oxide/hydroxide is utilized to at the same time eliminate low convergences of different pollutants by catching them inside the ferric mixtures. Iron co-precipitation viably eliminates selenite yet eliminates next to no selenate. This interaction has been generally utilized at mine destinations, and normally requires explanation and filtration downstream of the co-precipitation measure, as it produces a lot of slime.
3. ***Particle Trade (IX):*** In IX frameworks, selenate/selenite particles are traded for like-charged particles utilizing strength gums that are explicitly for selenium. The tar limit with regards to selenium can be expanded if contending anions, for example, nitrate, and sulfate are absent or are eliminated first. After the sap limit is reached, the sap requires recovery. This concentrated regenerant should then be discarded or further treated (Figure 10.2).

Figure 10.2. Selenium contains black and red isotopes.

Source: https://www.indiamart.com/proddetail/selenium-metal-powder-17932638233.html.

4. ***Adsorption:*** This uses a sorptive medium to diminish selenite and selenate to essential selenium. Like IX, the adsorption vessel is worked in up flow media. In contrast to IX, the medium cannot be recovered. Media regularly passes the toxicity characteristic leaching procedure (TCLP) when it is depleted. One medium that has been shown to be powerful for selenate evacuation is sulfur-changed iron (SMI) nanoparticles. Veolia prescribes an exclusive SeleniumZero® adsorption framework to either clean MBBR emanating or as an independent answer for lower-fixation streams.

Actuated alumina has been utilized for selenium evacuation by Pureflow Filtration and others. An adsorptive initiated alumina media and related compound treatment framework gives a robotized, low-upkeep treatment framework. Nonetheless, this cycle expects selenium to be in the selenite structure.

10.2.3. Selenite versus Selenate

Contrasts in treatment plans for diminished selenium (selenite) versus oxidized selenium (selenate) have been talked about. The primary undertaking for a potential treatment plot, obviously, is to distinguish the selenium oxidation state. Numerous insightful labs have this ability. Selenite is normally more straightforward to eliminate than selenate. Here

is a rundown of how the different treatment innovations can be applied to selenite and selenate (Figure 10.3).

Figure 10.3. Darkened structure of a selenium affected rock.

Source: https://www.industrialheating.com/blogs/14-industrial-heating-experts-speak-blog/post/94016-facts-about-the-elements-selenium.

10.3. OTHER DIFFERENT OPTIONS

Channel infusion has likewise been utilized for wastewaters containing selenium. Profound well infusion innovation was introduced in 2013 at a Southern California utility to determine ecological worries over its release of spent cooling-tower water to the Salton Sea (AGID, 2013). The primary worry here is the high capital expense of penetrating high-limit, profound (normally more prominent than 2,000 feet) wells equipped for keeping up with porousness over the long run (Hong et al., 2020).

A few advances to eliminate selenium from wastewaters have been applied, and more up to date advances have been created in the recent years, or they are right now being created. These innovations incorporate, yet are not restricted to, adsorption, and biosorption, layer partition advancements, coagulation/flocculation, oxidation/decrease strategies and phytoremediation. These advances will be examined here momentarily. The immediate precipitation of selenium compounds is of less significance, since selenium is generally found as oxyanions in wastewaters and is hence hard to hasten.

10.3.1. Adsorption

From a cleaner creation perspective, preventive measures to limit selenium delivery ought to be thought of and the treatment innovations ought to be assessed following the standards of green science. Adsorption is helpful for treating modern and metropolitan wastewaters which have low poison focuses. The principle disadvantage of adsorption is the shift of the contaminated medium, i.e., the impurity, from the water stage to a strong stage on which the toxin is concentrated, and as a rule, this adsorbent ought to be recovered before reuse, or treated preceding extreme removal. The adsorption limit (Qm) relies essentially upon the sort and attributes of the adsorbent being utilized. In any case, ecological boundaries like temperature, pH, serious metals, and so forth likewise assume a significant part in deciding the adsorption limit (Figure 10.4).

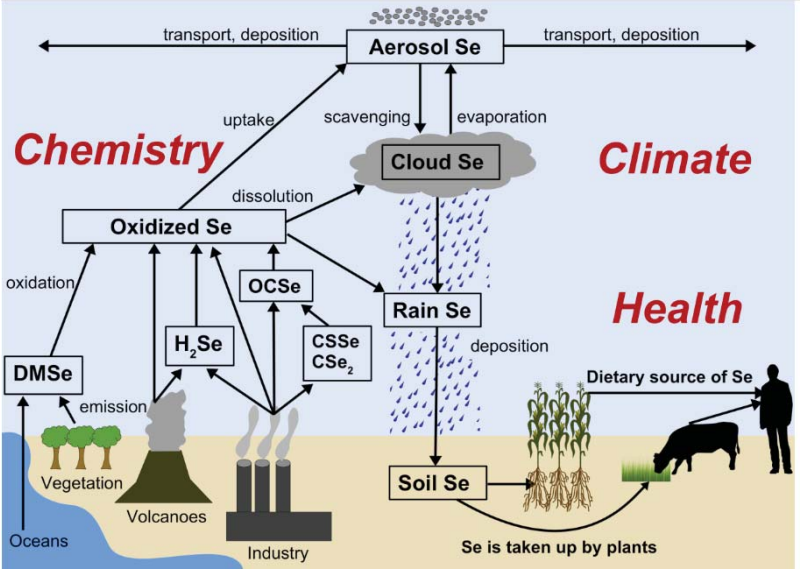

Figure 10.4. Selenium has adverse effects on the environment.

Source: https://iac.ethz.ch/group/atmospheric-chemistry/research/chemistry-climate-interaction/selenium.html.

The adsorption limit of a material can shows the amount of the adsorbate can be adsorbed on the adsorbent. A definitive adsorbent would be a substance or material through which the low release restricts that apply to selenium can be accomplished with as little of the adsorbent material as could really

be expected. In an optimal circumstance, a desorption interaction can be applied which recovers the adsorbent. Now and again, this is not plausible or just fractional recovery of the adsorbent is conceivable from the segment. After some time, the adsorbent will be immersed and will at this point do not have the ability to eliminate selenium and its oxyanions from wastewaters. The adsorbent then should be eliminated from the segment and supplanted with the new material. This interaction may prompt since a long time ago shut-down occasions and be definitely less savvy than basically washing and recovering the adsorbent.

The most extreme adsorption limits revealed in the writing (Santos et al., 2015) for selenium compounds on oxides, minerals, and carbon-based adsorbents range somewhere in the range of 0.22 and 120 mg/g. The adsorption of Se(IV) is viable in a wide scope of pH; then again, the evacuation of Se(VI) is more troublesome. Adsorption is inadequate at pH esteems more noteworthy than 10.0. The predominant selenium structure in acidic pH is selenious corrosive (H_2SeO_3). Between pH 3.5 and 9.0 for the most part biselenite ($HSeO_3^-$) anion happens, while at pH >9.0 selenite (SeO_3^{2-}) happens (El-Shafey, 2007a, b). The principle basic factor influencing the sorption rate is the sorbent surface. Film opposition likewise assumes a significant part in the solute's transmission (Zhang et al., 2009).

10.4. CORRELATION OF THE ADSORPTION LIMITS OF VARIOUS ADSORBENTS

Perhaps the most well-known sorbents utilized for adsorption is active carbon. To use it, first the carbon forerunner material ought to be cut into little pieces and washed with refined water to eliminate the debasements and air dried. An illustration of a carbon forerunner material is nut shell and in these examinations, the carbonization of the nut shell was done by sulfuric corrosive, at 170°C. It may likewise be directed by pyrolysis and microwave treatment. Se(IV) sorption on this sort of sorbent increments at higher actuation temperatures. This may be brought about by expanding the growing properties of the sorbent which makes more dynamic locales accessible for the evacuation of selenium particles (Figure 10.5).

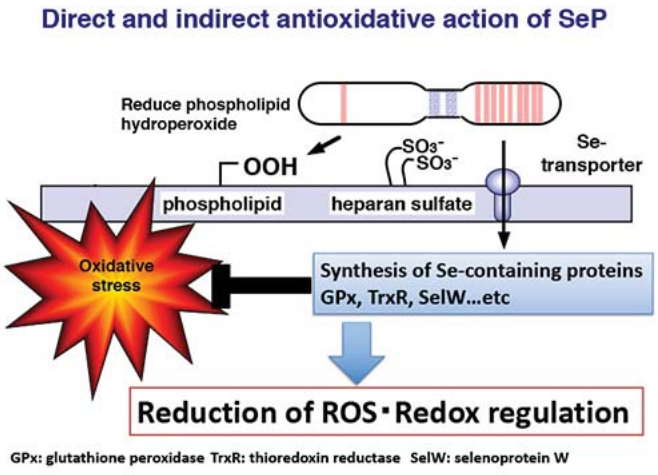

Figure 10.5. Oxidative stress is effective in selenium removal.

Source: http://www.pharm.tohoku.ac.jp/~taisya/english/index.html.

Minerals and nanoparticles can likewise adsorb selenium. Hydrous oxides of high valence metals have a high partiality to selenium oxo-anions which can frame frail form acids. It is deciphered by a particle trade instrument dependent on electrostatic communications. Ligand trade of anions with composed water may likewise be a decent decision for selenium evacuation. Suzuki et al. (2000) examined Se(IV) adsorption on Zr(IV)-EDTA intricate and announced that the maintenance of Se(IV) complex happens generally on the unsaturated site of Zr(IV) in the polymer. Polymer-Zr complex is truly steady, consequently, no spilling of zirconium happens. Indeed, even follow measures of selenium were taken out by the adsorbent containing Zr(IV). For the instance of Zr(IV)-EDTA unpredictable, the pH does not affect the adsorption rate steady since dissemination into the gum particles is the rate deciding advance. Accordingly, the response rate may be upgraded by expanding the surface space of the polymer. In another examination, the sorption limit of TiO_2 nanoparticles was explored (Zhang et al., 2009). The system of selenium adsorption was dominatingly dissemination in the limit layer and between the nanoparticles. Nano-TiO_2 has high adsorption limit. It successfully eliminates Se(IV) (>95%) from fluid arrangement in a pH scope of 2.0–6.0 (Zhang et al., 2009). Hematite and goethite are instances of minerals that likewise have shown great potential to adsorb selenium. For each case, the sorption of selenium diminishes at high pH in light of

overwhelming selenium species. For Se(VI), at basic pH, there are a lower measure of fluid species, i.e., $HSeO_4^-$. For Se(IV), the greatest sorption happens with the power of $HSeO_3^-$. In any case, in certain occurrences, the most extreme sorption limits can be miscounted and confused due to the surface complexation model, and it was accounted for that even at high selenium fixations, not the entirety of the dynamic locales were involved (Rovira et al., 2008).

10.4.1. Biosorption

Biosorption utilizes latent, non-living biomass as adsorbents to eliminate compounds from a framework by aggregating these mixtures in and around the cell mass of the living being included. At the point when normal materials or waste streams are utilized as the adsorbents, the more explicit term 'biosorption' is generally utilized in the writing. When living biomass is utilized to sequester metals inside the life form's cells, the term 'bioaccumulation' is utilized. In this cycle, the metal particle needs to pass the cell dividers of the life form included, which is just conceivable in living cells. Bioaccumulation is a much slower cycle than biosorption in view of the autonomy of metabolic energy in biosorption. Utilization of dead biomass is more valuable in modern applications than living cells. The biosorptive limit is more noteworthy and the dead biomass can be acquired from modern sources as a byproduct. Thus, dead cells are utilized all the more frequently in biosorption studies, and bioaccumulation is not examined further here (Figure 10.6).

The dead cell dividers can likewise be broken, giving extra restricting destinations and moderate sorption pace of bioaccumulation. The materials utilized as the biosorbent ought to be somewhat more affordable, and they ought to be accessible in enormous amounts locally. The biosorbents can even come from biomass that is generally considered as a byproduct. Some run of the mill materials that are utilized as biosorbents (either in unique or in altered structure) for the evacuation of substantial metals and mining water containing selenium are cells of microorganisms, parasites, and microalgae, kelp, plant tissues, handling waste from plants and creatures, for example, natural product skins and crab and shrimp shells. The vast majority of the biosorption examines utilize bunch tests where a shut framework with a known grouping of a specific toxin is acquainted with a biomass. The shut framework is disturbed to keep up with the biomass under suspension conditions and to guarantee great contact between the poison and the sorbent (He et al., 2018).

Figure 10.6. Microbial bioabsorption of selenium.

Source: https://www.intechopen.com/books/biosorption/microbial-based-bio-remediation-of-selenium-and-tellurium-compounds.

In group tests, boundaries like pH, temperature, contact time, and so on are generally shifted from low to significant levels to analyze their impact on the evacuation capability of the contemplated biomass. In many investigations, optimal working conditions are resolved, which consequently yield the most noteworthy sorption potential. Working with a ceaseless arrangement is more mind boggling and, for this situation, for the most part advancement bends are resolved. Tests of profluent are taken at pre-decided time stretches and their focus is estimated. The outcomes are contrasted with the underlying focus. At the point when the gushing fixation rises to the underlying metal/selenium centralization of the wastewater, the biomass is viewed as immersed and no more contamination can be held. The outcomes from persistent examinations were initially communicated in units of μg/g.

The expulsion of toxins by biosorption measure depends on a few complex systems that are represented and handily influenced by mass exchange and warmth move properties. The fundamental systems associated with biosorption are adsorption, particle trade, surface complexation, particle ensnarement in intra-and interfibrillar vessels, chelation, and precipitation. As a rule, there are numerous useful gatherings present on the phone divider locales of the living beings that could draw in and sequester

the objective toxins. The piece varies for each kind of biomass, however the main designs for metal biosorption are carboxyl, carbonyl, hydroxyl, thiol, sulfonate, thioether, amine, optional amine, amide, imidazole, phosphonate, and the phosphodiester bunch. For certain sorts of biomass, at least one ordinary practical gathering can be distinguished that are answerable for doing the biosorption cycle. For instance, the acetamido bunches are the useful gatherings that advance biosorption in chitin, carboxyl, and sulfates. This useful gathering is available in the polysaccharides of marine green growth, underlying polysaccharides in parasites, and hydroxyl bunches present on lignin and hemicellulose in straw. Other than the presence of useful gatherings, different components will likewise impact the biosorption conduct. Temperature, pH, explicit surface space of the biosorbent, the presence of contending metal particles, pre-treatment of the biosorbent, introductory biomass and metal particle focus are significant elements that can impact the productivity of the biomass as a sorbent.

10.4.2. Use of Microbial Biomass as Biosorbents for the Expulsion of Selenium

Selenium treatment from any modern wastewater is difficult for specialists and plant administrators. In the first place, in some wastewater, selenium focus is extremely low and it is actually and financially hard to treat utilizing traditional treatment advancements. Second, the allowable release limit for selenium in treated water is exceptionally low (5 μg/L or even less). Regular advances neglect to get the profluent meet this cutoff by and large. Third, in view of its perplexing synthetic nature and meddling synthetics present in wastewater that contains selenium, change in substance speciation may regularly cause the treatment cycle to be inadequate. Likewise, changing toxin focus is additionally an obstacle for a traditional treatment framework to treat selenium. At long last, there is trouble in the administration of removal of buildups and results that are created from the traditional treatment innovations to treat selenium. This load of components has guided the examination of selenium evacuation to biosorption-based advances (Figure 10.7) (Kaur et al., 2021).

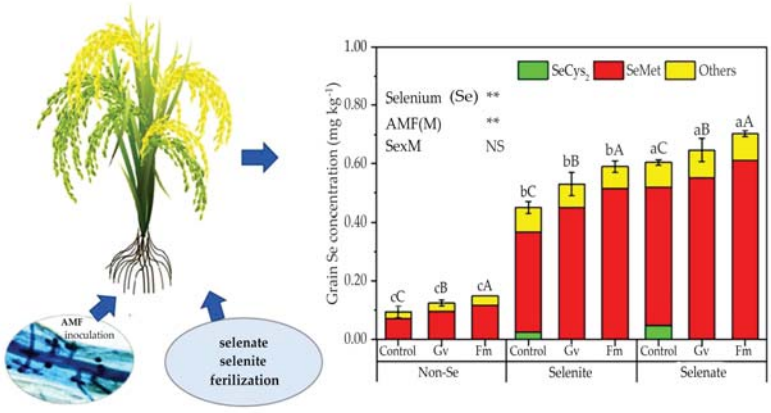

Figure 10.7. Selenium can accumulate in crops if left in the open.

Source: https://www.sciencedirect.com/science/article/abs/pii/S0048969720346957.

Distinctive microbial biomass has drawn in incredible consideration in the field of metal and metalloids remediation from wastewater. The naturally dynamic atoms have a fondness to tie certain particles or particles from the fluid medium. The adsorption of issue happens on the organic material because of the natural exercises in live/living cells or metal restricting utilitarian gatherings of cells in both living and dead cells. For the most part, the utilization of microorganisms as adsorbents has demonstrated to be a proficient, practical, and safe strategy for the evacuation of various metals and metalloids. Likewise, biosorption procedures lead to the minimization of synthetics in the wastewater treatment area. This biocatalyst-based innovation can likewise decrease chalcogen oxyanions under room temperature, standard climatic pressing factor, and impartial pH. The innovation is additionally ready to meet the administrative furthest reaches of selenium in wastewater. Uncommon kinds of microorganisms are impervious to selenium oxyanions and can diminish them to their essential structures.

To keep away from harmfulness and the necessity of development medium that would expand the functional expenses, dead biomass is liked. Use of dead biomass for biosorption additionally permits desorption of the adsorbed selenium with the end goal of asset recuperation. The utilization of dried, non-living, or artificially pre-treated microorganisms has all the earmarks of being promising for selenium evacuation. Living cells, after

physical and substance treatment, have additionally shown great execution in the biosorption cycle. A few examinations have revealed the bioremediation of selenium utilizing microorganisms like parasites, yeast, microbes, and green growth.

10.4.3. Microscopic Organisms

Use of microscopic organisms as a biosorbent offers the accompanying benefits: it takes less time, gives better hereditary dealing with and is not difficult to oversee. Various kinds of heterotrophic high-impact and anaerobic and chemotropic microscopic organisms have been utilized for the decrease of selenium oxyanions and to treat wastewater sullied with selenium. Microorganisms can lessen selenate to selenite and further to basic selenium, selenide, and natural selenium. Various types of microbes, for example, *Wolinella succinigenes*, *Pseudomonas stutzeri*, *Bacillus* sp. SF-1, *Bacillus selenitireducens*, *Pseudomonas* sp. strain CA5, Bacillus sp. strain STG-83 have been tried effectively for the decrease of Se(IV). Essentially, *Citerobacter freundii*, *Citerobacter braakii*, *Enterobacter taylorae*, *Bacillus* sp. strain STG-83 have been utilized to lessen Se(VI) (Figure 10.8) (Kashiwa et al., 2000).

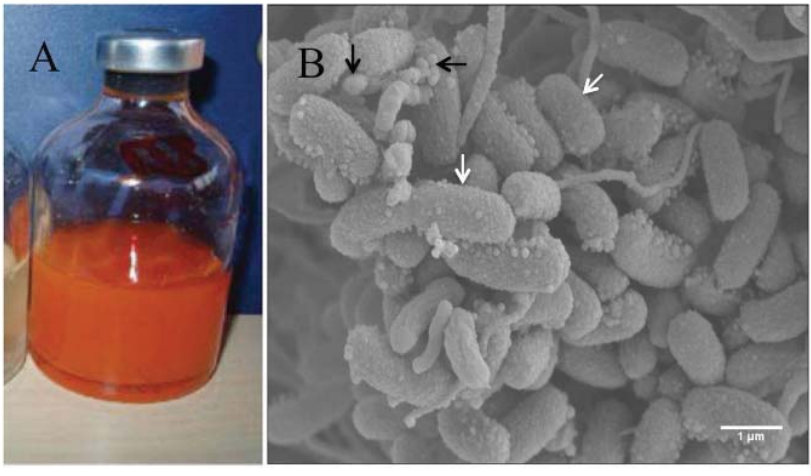

Figure 10.8. Biotechnology of selenium.

Source: https://journals.asm.org/doi/10.1128/mmbr.00037-14?permanently=true&.

Twidwell et al. (1999) exhibited the utilization of *Pseudomonas stutzeri*, which can lessen both Se(IV) and Se(VI). The microorganisms were developed on carbon surfaces pre-treated with biopolymers and the biofilm was made. From there on, the compounds from the microscopic organisms were separated. The biofilm and chemicals were treated with 620 μg Se(IV)/L in high-impact bioreactors. The biofilm-based reactor delivered profluent containing <10 g Se/L for almost nine months of activity without accomplishing forward leap. Then again, the catalyst-based reactor created effluents containing similar measure of selenium with forward leap following four months of persistent activity. Tan et al. (2018) analyzed the presentation of a biotrickling channel and an up flow anaerobic slop cover (UASB) reactor for the treatment of a model mining wastewater tainted with SeO_4^{2-} and SO_4^{2-}. Albeit the Se evacuation execution of the UASB reactor was not influenced by the presence of SO_4^{2-}, the outcomes from that review showed that the presentation improved by >70% utilizing the biotrickling channel biofilm. *Pseudomonas stutzeri* NT-I can decrease the selenium up to a centralization of 10 mM as Se(VI) and 9 mM as Se(IV), separately. In that review, the test conditions were as per the following: pH scope of 7.0–9.0 and temperature 20–50°C for selenite decrease and pH 6.0–9.0 in the temperature scope of 20–50°C for selenite decrease (Kunhikrishnan et al., 2017).

Pieniz et al. (2011) has detailed the Se(IV) bio-adsorption limit of Enterococcus species. A sum of 36 Enterococcus species were secluded from dairy item among which two species, specifically, *Enterococcus faecalis* and *Enterococcus faecium*, developed ideally and had the option to eliminate selenium at an underlying pH of 7.0 and at a temperature of 25°C. Following 24 hours, these species had the option to eliminate 9.9 mg/L and 59.7 mg/L of selenite, separately. Additionally, in a connected report (Fujita et al., 2002), the decrease of selenate into essential selenium utilizing Bacillus sp. SF 1 in an anaerobic ceaseless stream reactor was noticed. Inside a short maintenance time, selenate was decreased; notwithstanding, the creators announced an aggregation of selenite. At longer maintenance times, both oxyanions were changed over into basic selenium which is non-poisonous in nature.

10.4.4. Fungi

In the field of ecological biotechnology, fungi, and yeast have a unique spot. The fast multiplication of their cells, hereditary variety and simple

morphological and hereditary control capacities, endurance in a wide scope of natural conditions like temperature and pH have caught the interest of analysts for their utilization as potential biosorbents. Other than these, the waste biomass is likewise accessible liberated from cost whenever got as a side-effect from the businesses. On the off chance that the biomass must be developed, it tends to be handily developed without the utilization of costly innovation and development medium (Kuyucak, 1990). Despite the fact that the utilization of parasitic and yeast biomass has been investigated for the adsorption of various kinds of substantial metals, exceptionally restricted examinations are accessible in the field of selenium biosorption utilizing contagious biomass (Kapoor et al., 1995). Species, for example, Saccharomyces cerevisiae (Li et al., 2013), *Rhodotorula mucilaginosa*-13B (Ruocco et al., 2014), and Lactobacillus plantarum (Calomme et al., 1995) have been utilized for the biosorption of selenium. Parasites and yeast can tie selenium in its natural and inorganic structures. They can bioaccumulate selenium intracellularly just as extracellularly. During the extracellular restricting of selenium proteins, phospholipids or polysaccharides assume a functioning part to shape an ionic bond or complexation of selenium. On account of intracellular collection, dynamic transportation of selenium happens in the insides of the cells (Figure 10.9) (Kieliszek et al., 2015).

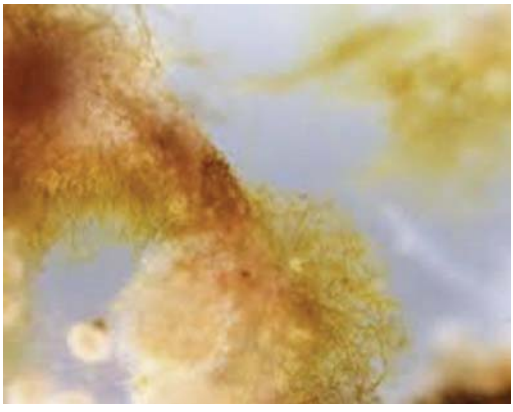

Figure 10.9. Fungi is a natural remedy for selenium through biosynthesis.

Source: https://sciworthy.com/more-than-decomposers-fungi-influence-the-recovery-of-pollutants-in-the-environment/.

Utilization of *Saccharomyces cerevisiae* to sequester selenium in various oxidation states was concentrated by Pérez-Corona et al. (1997).

The creators detailed that the reliance of Se(IV) bioaccumulation relied upon variables, for example, temperature, and the measure of biomass utilized, however Se(VI) showed low partiality to the biomass. The arrangement pH did not influence the gathering of Se(IV). In a new report (Espinosa-Ortiz et al., 2015), the limit of *Phanerochaete chrysosporium*-a white decay parasite-was tried for the fruitful expulsion of selenite from manufactured wastewater in a persistently streaming bioreactor. During the 41 days of reactor activity, the creators revealed ~70% absolute solvent Se expulsion at a constant Se stacking pace of 10 mg Se/L/day. Moreover, morphological changes in the parasites were additionally seen because of the intracellular creation of natural selenium nanoparticles.

As per Gharieb et al. (1995), among the various organisms tried, *Fusarium* sp., *Trichoderma reesei*, *Aspergillus niger*, Mucor SK and *Rhizopus arrhizus* were the species that had the option to decrease selenite to its basic structure. On account of Fusarium sp. what is more, *Trichoderma reesei*, the contagious cells could lessen selenite in Czapek-Dox agar medium, while the other three species had the option to decrease selenite when developed on malt separate agar. Additionally, Marinescu et al. (2011) showed the selenium adsorption limit of *Saccharomyces uvarum* when it was treated with sodium selenite at various temperatures, pH, selenium focuses, and biomass extents, utilizing two sorts of agar (malt wort and sparge water). In that review, at starting fixations in the scope of 30–180 μg/mL sodium selenite, gathering of selenium was seen in the scope of 0.6–2.2 mg/g for malt wort and 0.3–0.9 mg/g for sparge water, separately. Nettem and Almusallam (2013) examined the impact of various boundaries like pH of the arrangement, adsorbent portion, beginning metal particle fixation, contact time and temperature on the biosorption of selenium utilizing Ganoderma lucidum biomass. The adsorption limit was discovered to be 127 mg/g. Fourier change infrared spectroscopy (FT-IR) investigation of the contagious cells recommends that amino, carboxyl, hydroxyl, and carbonyl gatherings were answerable for working with the biosorption cycle.

10.4.5. Green Algae

Marine green algae or kelp are additionally regularly read microorganisms for the biosorption of selenium from polluted water. They are alluring biosorbents due to the high metal restricting limit because of the presence of polysaccharides, proteins, or lipid on their phone divider. They contain useful gatherings like amino, hydroxyl, sulfate, and carboxyl gatherings which go about as restricting locales for metal and metalloid expulsion (Shelef, 2018).

What is more, green growth are normally bountiful species, inexhaustible, and consequently a financially savvy biosorbent (Tuzen and Sarı, 2010). Mane et al. (2011) researched the impact of pre-treatment of Spirogyra sp. on the selenium biosorption limit. For this reason, the biomass was exposed to warm, autoclaving, and compound treatment with sodium hydroxide and acidic corrosive. This physical and synthetic treatment positively affected the adsorption limit of selenium, wherein most extreme metal evacuation was accomplished utilizing autoclaved biomass (Figure 10.10).

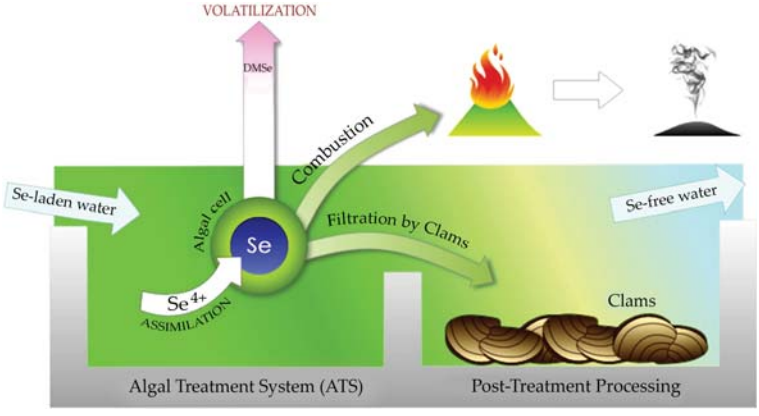

Figure 10.10. Green algae are commonly used in extracting selenium.

Source: https://www.sciencedirect.com/science/article/abs/pii/S0304389418310343.

In another investigation, the waste biomass of Gracilaria created after the business creation of agar showed a fondness to adsorb Se(IV) and Se(VI) after the biomass was treated with a ferric arrangement and changed over into biochar through lethargic pyrolysis (Roberts et al., 2015). Despite the fact that the biosorption limit of this biochar was lower (2.7 mg/g), this was the main endeavor to show the adsorption capacity of Gracilaria altered biochar. Another investigation by Johansson et al. (2015) exhibited the use of Gracilaria changed biochar to eliminate 98% of Se(VI) from mock arrangement.

10.4.6. Membrane Partition Technologies

The regular film detachment technology comprises of microfiltration, ultrafiltration, nanofiltration, and converse assimilation. Among these, lone nanofiltration and converse assimilation are fit for isolating selenium

compounds from a debased wastewater stream. Kharaka et al. (1996) showed that the utilization of nanofiltration was able to do specifically eliminating 95% of selenium from profoundly tainted water. Sunlight based controlled ultrafiltration-nanofiltration/switch assimilation frameworks depicted by Richards et al. (2008) were fit for eliminating 74–94% of the at first present selenium focuses in Australian groundwaters. Additional proof of selenium evacuation by nanofiltration or opposite assimilation is, no doubt, extremely scant in the logical writing. Twidwell et al. (1999) expressed that opposite assimilation is recorded as a standout amongst other accessible innovations (BATs) by the USEPA, however that further modern execution of this innovation is presumably impeded by the way that the answers for be dealt with contain extremely weaken centralizations of solids, which is regularly not the situation for mechanical wastewaters like corrosive mining wastewaters. Hence, pre-treatment is required and turn around assimilation for selenium expulsion from contaminated waste streams must be utilized as a last cleaning step, regularly depicted in the writing as a post-treatment step (Figure 10.11).

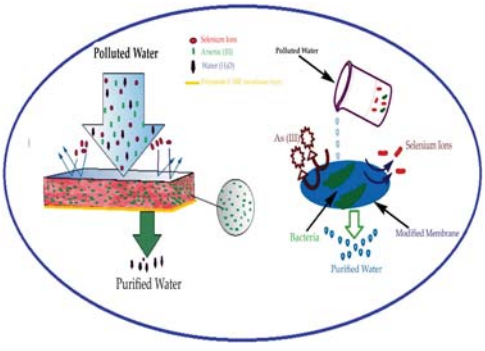

Figure 10.11. Selenium can be removes using nanofiltration.

Source: https://www.sciencedirect.com/science/article/abs/pii/S2214714420300544.

10.4.7. Coagulation or Flocculation

Coagulation or flocculation is a generally utilized procedure in wastewater and drinking water treatment. The colloidal and suspended particles that cannot be settled gravitationally can be hastened by destabilization of the charged particles. The coagulants that are utilized normally are Fe_3^+ and Al_3^+ salts that hydrolyze precipitously when added to water, to shape a

progression of metastable hydrolysis items. At the point when emphatically charged, these hydrolysis items can kill adversely charged particles and would thus be able to balance the unpleasant powers. When impartially charged (i.e., $Fe(OH)_3$ or $Al(OH)_3$), the coagulants can frame huge totals that can encase the impurities in their thickly enmeshed organization while accelerating (Figure 10.12) (Staicu et al., 2015).

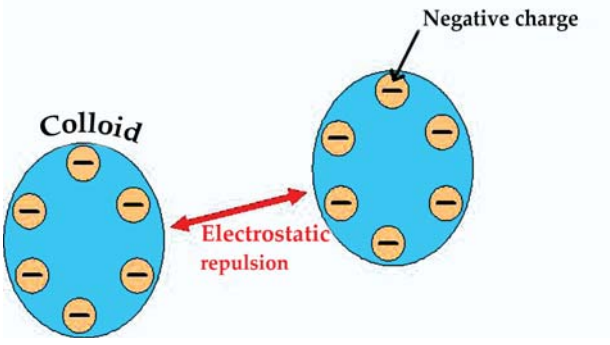

Figure 10.12. Water treatment coagulation of selenium.

Source: https://www.thewatertreatments.com/wastewater-sewage-treatment/coagulation-types/.

Coagulation/flocculation has demonstrated to be compelling for the expulsion of a few harmful metals and metalloids. Notwithstanding, for the evacuation of selenium, writing data is fairly scant. Staicu et al. (2015) thought about the evacuation of colloidal Se(0) from wastewater by centrifugation, filtration, and coagulation/flocculation with aluminum sulfate or ferric chloride. As indicated by the creators, coagulation/flocculation accomplished the most noteworthy evacuation (92%) contrasted with centrifugation (91% at 4,500 rpm, 73% at 3,000 rpm and 22% at 1,500 rpm), filtration over a 0.45 μm channel (87%) and coagulation/flocculation with ferric chloride (43%). Moreover, Se(0), Se(IV) and Se(VI) were additionally eliminated by coagulation/flocculation. Hu et al. (2015) saw that the evacuation of Se(IV) was substantially more articulated than the expulsion of Se(VI), yet in addition that the Fe-based coagulants were considerably more compelling than the Al-based coagulants.

10.4.8. Oxidation/Decrease

Oxidation/decrease measures are just only occasionally utilized for the remediation of selenium-containing waters and soils. In spite of the Cr(VI)/

Cr(III) frameworks where just the portable compound (Cr(VI)) can be changed over to a less dissolvable one and the accelerated structure (Cr(III)), the normally common types of selenium (i.e., Se(IV) and Se(VI)) are profoundly solvent. In this manner, decrease to metallic selenium and ensuing precipitation can diminish the selenium levels. This technique has effectively been applied previously and it very well may be utilized to eliminate other undesirable parts (Plotnikov, 1960). Then again, for the decrease of Se(IV) or Se(VI) to their metallic express, a solid lessening specialist is required which makes the entire cycle horrible. Rather than utilizing solid decreasing specialists, Se-diminishing microscopic organisms can likewise be utilized. Cantafio et al. (1996) performed tests with the selenate-breathing bacterium *Thauera selenatis* in a pilot scale organic reactor and had the option to decrease the selenium content in the tried agrarian waste water by 98%. Selenate was diminished to natural Se and could be recuperated utilizing a precipitant-coagulant. Fruitful endeavors to diminish selenite to essential Se utilizing microbes were performed with *Geobacter sulfurreducens*, *Shewanella oneidensis* and *Veillonella atypica* (Pearce et al., 2009) and Rhodospirillum rubrum (Kessi et al., 1999), separately.

10.4.9. Phytoremediation

Phytoremediation is characterized as the expulsion of poisons from polluted soils, water, or air by plants (Lee, 2013). The plants can either collect or potentially detoxify the harmful components. It tends to be utilized for metals and metalloids, explosives, solvents, pesticides, and so on It is a generally economical method contrasted with unearthing and *ex situ* remediation of a sullied soil. The cleanup can be acted *in situ* and no outside supply of energy is needed to develop the plants; in any case, some energy might be needed for gathering the biomass. Handling the biomass to yield energy (e.g., by cremation with energy recuperation, pyrolysis, or anaerobic processing) can, in its turn, create some benefit, while the poisons moved in the remains can be removed and sold (phytomining) (Li et al., 2017). One detriment of phytoremediation is that it is an exceptionally lethargic cycle and it can require quite a while to tidy up a tainted site (Figure 10.13).

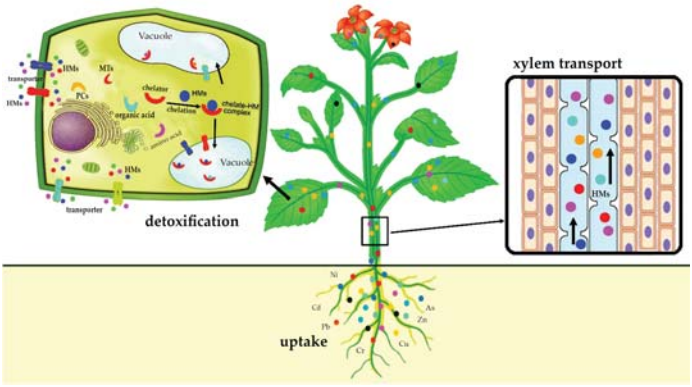

Figure 10.13. Plants can help combat selenium contamination.

Source: https://www.frontiersin.org/articles/10.3389/fpls.2020.00359/full.

The compelling expulsion of selenium from debased soils and waters by phytoremediation has been exhibited as of late. Tests with built wetlands vegetated with solid bulrush, Baltic surge, smooth cordgrass, rabbit foot grass, salt grass, cattails, tule, widgeon grass, or a mix thereof showed an expulsion of 59% selenium from the water stage. Other effective selenium phytoremediation considers were performed with broccoli plants, wheat (Li et al., 2008), cattails (Huang et al., 2012) and water hyacinths. Another promising methodology is the ID of novel qualities from normal selenium hyper gatherers and their resulting move to quickly developing species (LeDuc and Terry, 2005).

10.5. DIFFICULTIES IN SELENIUM ADSORPTION AND FUTURE DIRECTIONS IN SELENIUM REMOVAL TECHNOLOGIES

In view of the writing audit, the greater part of the flow research centers around Se(IV) and Se(VI) expulsion, however the principle issue is the evacuation of the natural type of selenium. It has higher bioavailability and bioaccumulates more quickly than other selenium compounds. It is created during the decrease of selenium compounds by microbes and presumably identified with the measures of solvent natural materials utilized by the microorganisms for this cycle (Zhang and Frankenberger, 2005). Further examination ought to likewise zero in on understanding the instrument of biosorption in move through frameworks that reproduce normal springs. For

instance, when the pH is higher than the pKa of a useful gathering, that gathering is adversely charged and has liking to metal cations. Unexpectedly, when the pH dips under the pKa esteem, it is soaked by protons and has positive charge and can adsorb oxyanionic pollutants all the more proficiently (Roberts et al., 2015). In this manner, it is apparent that the accessibility of practical gatherings for metal adsorption and metal speciation relies upon the common pH of the water. Cationic biosorption is impacted by pH and the component of take-up varies from cation biosorption to unmanipulated biosorbents (Roberts et al., 2015). Another issue about which insufficient is known is the level of selenium relationship with natural matter. The cycling of selenium affects the biotic interaction. By and by, in the writing, there is an absence of robotic portrayal of these cycles and their systems (Fernández-Martínez and Charlet, 2009).

As talked about already, it is as yet hard to evaluate the issues of selenium lack/harmfulness in living beings. A profound comprehension of the various sorts of adversarial or synergistic associations between selenium/soil/water/plants might be useful. Assurance of selenium structures which ought to be taken if there should be an occurrence of selenium insufficiency and recognizing the best remediation techniques for tainted destinations actually represent an issue on the grounds that at present they are done on a case-to-case premise. The utilization of spectroscopic devices would permit the selenium adsorption interaction to be learned at the nanoscale. The utilization of such instruments will expand our insight about selenium maintenance at the mineral/water interface and it is useful to propose a fitting treatment framework for selenium expulsion from defiled destinations. As seen from the writing, the intricate geochemistry of selenium causes complex connections between the mineral stages and natural matter. Albeit, in certain cases, the systems associated with the arrangement of natural matter-metal-selenium edifices are known, data on their steadiness constants and compound construction under various ecological conditions are scant (Fernández-Martínez and Charlet, 2009).

One of the promising substances utilized for selenium adsorption is a complex of zirconium with polymer sap. It adsorbs follow measures of selenium and arsenic (Suzuki et al., 2000). Gracilaria-changed biochar has demonstrated to be compelling for the adsorption of Se(IV) and Se(VI) from watery arrangements, as opposed to existing selenium treatment advancements (Roberts et al., 2015). This would likewise work on the solidness of Gracilaria development by diverting the unused waste for the treatment of selenium containing wastewaters. From a commonsense

perspective, in places like the Kesterson repository (USA), which is a characteristic selenium tainted site, specialists are as yet examining reasonable choices for treatment. In such conditions, selenium nano-encourages are intrinsically created because of biotic responses with the neighborhood climate albeit the reactivity and surface science of the nano-hastens are as yet not known. Further exploration toward this path would be essentially useful to enlarge the information about the reactivity of selenium nanoparticles just as their destiny in the ecosystem.

10.6. FINAL REMARKS

The diverse physico-substance and organic treatment innovations accessible for the expulsion of selenium oxyanions, specifically, selenite, and selenate, were inspected. It is essential to specify that a portion of these advances are regularly costly on the grounds that the expulsion of selenium from a contaminated water/soil climate is a mind-boggling measure and as far as possible are fairly tough. Additionally, the presence of natural matter, contending particles, broken up solids and different metals or metalloids in the water meddles with the level of treatment accomplished. In such circumstances, it is fitting to carry out a half breed or two-venture measure, i.e., in the main stage, the selenium oxyanions can be specifically adsorbed onto the dynamic locales of a sorbent material (first stage adsorption) or naturally oxidized/diminished (first stage bioreactor) and, in this manner, in the subsequent stage, the excess non-treated contending mixtures can be eliminated. The utilization of a mixture interaction, like mix of electrocoagulation (EC) and film filtration or adsorption and precipitation, is required to yield promising outcomes for the expulsion of selenium present in mining water. The survey closes with the idea of two promising substances (both synthetic and natural) for selenium adsorption-a complex of zirconium with polymer pitch and Gracilaria-changed biochar. The destiny of selenium nano-hastens in the climate actually stays obscure. Further examination toward this path would be essentially useful to develop the information about the reactivity of selenium nanoparticles just as their destiny in the indigenous habitat.

Essential selenium is somewhat insoluble in watery frameworks and not organically dynamic, which makes evacuation a lot easier and forestalls bioaccumulation. Having said that, the most widely recognized type of selenium delivered during the recently referenced mining measures are the watery structures, selenite, and selenates, which are water dissolvable

oxyanions. The most widely recognized advances to date can be summarized in these significant classifications: media filtration, substance treatment, and biomediated evacuation. Notwithstanding, notice that to date, there is certainly not a conclusive answer for the difficult ecological pollution with selenium (Golder, 2009). Actual Treatment Media filtration is an actual treatment strategy. These can be just about as straightforward as sifting through sand (Kuan, 1998), mud (Goh, 2004), titanium dioxide (Zhang, 2009), or can be pretty much as extraordinary as separating through particle trade saps or a layer (switch assimilation and nanofiltration) (Stripeikis, 2001). A significant number of these media are regularly utilized in the water treatment industry. Two normal issues related with filtration media are the expanded measure of waste, and the potential for fouling or scaling of the layer. A considerable lot of these sorts of techniques additionally have sensitivities to different particles like nitrates, sulfates, and chlorides, which lead to the powerlessness to eliminate selenates. Layer filtration is a strategy that is generally utilized, yet can be very exorbitant.

Because of the comparative substance nature and reactivity of sulfates and selenates, it is very hard to isolate the two utilizing a particle trade pitch; in this manner, a critical presentation decline is seen in sulfate rich conditions. This presentation diminishing can be overwhelmed by driving the arrangement of a barium scale by means of the expansion of $BaCl_2$. A blend of precipitation/particle trade can lessen selenium tainting levels from 1,000 ppm to 0.1 ppm. Saps can likewise be cleaned and reused, leaving a concentrated selenium waste to be discarded. As referenced already, the enormous amounts of waste created is a huge concern when thinking about such a treatment strategy. Synthetic Treatment Chemical treatment can be arranged into three classes: precipitation (Zhang, 2008; Rovira, 2008; Hayashi, 2009; Geoffroy, 2010), cementation, and coagulation (Golder, 2009). The treatment works by changing the physical or synthetic properties of the broke down toxin or suspended matter such that will improve the capacity to agglomerate. The particles would then be able to be eliminated by buoyancy, filtration, or gravity settling. Coagulants (Ferrous, Ferric, Aluminate) work by changing the surface charge of the foreign substances, in this manner considering the agglomeration of the particles into a flocculated hasten. The floc size can be expanded by the expansion of a polymeric flocculant, for example, polyacrylamides. Selenites are effortlessly eliminated utilizing any of these techniques; notwithstanding, selenates are not as responsive. To eliminate the greater part of the selenate pollution with a compound treatment technique, a decrease step should be joined. Another significant

detriment of most synthetic treatment prospects is in the high amount of synthetics being burned-through, therefore prompting the need to treat the subsequent strong waste.

In dynamic microbial decrease process, measure water is added to the lower part of a reactor where the water streams up into a microbial "slop." It is in this microbial "slop" where the selenates and selenites are diminished to selenium, which is then eliminated from the highest point of the reactor. The writing records molasses, wood chips, and distiller's grains as conceivable media for such microbial movement (Golder, 2009). Be that as it may, one of weaknesses of the microbial decrease measure is the raised groupings of all out suspended solids; a fruitful microbial decrease would require pretreatment. Such a cycle has been applied at the USEPA Kennecott site for a half year, and information recommends a decline in selenium from 1,950 ppb to under 2 ppb. This interaction was additionally applied at Duke Energy in North Carolina within the sight of high complete disintegrated solids, bringing about a 99.3% decrease in selenium following 9 months. Notwithstanding the high capital expenses related with this method, another burden is the microbial upkeep of boundaries like supplements, energy, and temperature that is needed to support sufficient decrease. Another biomediated course to eliminating selenium is through biofilms. The writing recommends that this is a course that can likewise be applied to selenium expulsion. The utilization of *Desulfomicrobium* sp. was demonstrated to diminish the selenate fixation to sub-micromolar focuses when lactate and sulfate were utilized as the development media (Hockin, 2006). In restricted degrees of sulfate focuses, the prevailing types of selenium estimated is selenide; notwithstanding, at an overabundance of sulfates, the selenate is enzymatically decreased to selenium. Notice that a detriment to this strategy is the decline of action saw within the sight of raised nitrate levels. Dissimilar to most of the other biomediated pathways, detached microbial decrease has a generally low capital cost. It is fruitful at diminishing both selenite and selenate with insignificant oversight required, however will leave a lot of waste. This technique is additionally temperature touchy and requires a critical expansion in measure time. There are other biotreatment strategies, however a large number of them require anaerobic conditions that might be hazardous on the mechanicals.

Low degrees of selenium can wind up in soils or water through enduring of rocks. It will then be taken up by plants or end up in air when it is adsorbed on fine residue particles. Selenium is destined to enter the air through coal and oil ignition, as selenium dioxide. This substance will be changed over

into selenium corrosive in water or sweat. Selenium substances in air are normally separated to selenium and water decently fast, with the goal that they are not hazardous to the strength of living beings. The conduct of selenium in the climate emphatically relies on its collaborations with different mixtures and the natural conditions at a specific area at a specific time.

There is proof selenium can amass in the body tissues of life forms and can then be left behind through the natural pecking order. Generally, this bio amplification of selenium begins when creatures eat a great deal of plants that have been engrossing a lot of selenium, before absorption. Because of water system run-off convergences of selenium will in general be extremely high in oceanic life forms in numerous spaces. At the point when creatures ingest or aggregate high convergences of selenium it can cause regenerative health conditions.

BIBLIOGRAPHY

1. Ali, W., Zhang, H., Junaid, M., Mao, K., Xu, N., Chang, C., & Yang, Z., (2021). Insights into the mechanisms of arsenic-selenium interactions and the associated toxicity in plants, animals, and humans: A critical review. *Critical Reviews in Environmental Science and Technology, 51*(7), 704–750.
2. Badr, N. B., Al-Qahtani, K. M., & Mahmoud, A. E. D., (2020). Factorial experimental design for optimizing selenium sorption on *Cyperus laevigatus* biomass and green-synthesized nano-silver. *Alexandria Engineering Journal, 59*(6), 5219–5229.
3. Bailey, R. T., (2017). Selenium contamination, fate, and reactive transport in groundwater in relation to human health. *Hydrogeology Journal, 25*(4), 1191–1217.
4. Banuelos, G. S., Lin, Z. Q., Wu, L., & Terry, N., (2002). Phytoremediation of selenium-contaminated soils and waters: Fundamentals and future prospects. *Reviews on Environmental Health, 17*(4), 291–306.
5. Bini, C., (2009). Soil restoration: Remediation and valorization of contaminated soils. Manual of methods for soil and land evaluation. *Science Publisher, Enfield (NH)*, 137–160.
6. Buchs, B., Evangelou, M. W., Winkel, L. H., & Lenz, M., (2013). Colloidal properties of nanoparticular biogenic selenium govern environmental fate and bioremediation effectiveness. *Environmental Science and Technology, 47*(5), 2401–2407.
7. Charya, L. S., (2017). Selenium pollution in the marine environment and marine bacteria in selenium bioremediation. In: *Marine Pollution and Microbial Remediation* (pp. 223–237). Springer, Singapore.

8. Cooper, J., (2021). Harnessing biogeochemical principals for remediation of selenium-contaminated soils. *Selenium Contamination in Water,* 267–296.

9. Déon, S., Deher, J., Lam, B., Crini, N., Crini, G., & Fievet, P., (2017). Remediation of solutions containing oxyanions of selenium by ultrafiltration: Study of rejection performances with and without chitosan addition. *Industrial and Engineering Chemistry Research, 56*(37), 10461–10471.

10. Domokos-Szabolcsy, É., Fári, M., Márton, L., Czakó, M., Veres, S., Elhawat, N., & Alshaal, T., (2018). Selenate tolerance and selenium hyperaccumulation in the monocot giant reed (*Arundo donax*), a biomass crop plant with phytoremediation potential. *Environmental Science and Pollution Research, 25*(31), 31368–31380.

11. El-Ramady, H., Faizy, S. E. D., Abdalla, N., Taha, H., Domokos-Szabolcsy, É., Fari, M., & Brevik, E. C., (2020). Selenium and nano-selenium biofortification for human health: Opportunities and challenges. *Soil Systems, 4*(3), 57.

12. Feng, R., Zhao, P., Zhu, Y., Yang, J., Wei, X., Yang, L., & Ding, Y., (2021). Application of inorganic selenium to reduce accumulation and toxicity of metals and metalloids in plants: The main mechanisms, concerns, and risks. *Science of the Total Environment*, 144776.

13. Frankenberger, W. T., Amrhein, C., Fan, T. W. M., Flaschi, D., Glater, J., Kartinen, E., & Toto, A., (2004). Advanced treatment technologies in the remediation of seleniferous drainage waters and sediments. *Irrigation and Drainage Systems, 18*(1), 19–42.

14. Garousi, F., Kovács, B., Andrási, D., & Veres, S., (2016). Selenium phytoaccumulation by sunflower plants under hydroponic conditions. *Water, Air, and Soil Pollution, 227*(10), 1–11.

15. Hasanuzzaman, M., Bhuyan, M. H. M., Raza, A., Hawrylak-Nowak, B., Matraszek-Gawron, R., Nahar, K., & Fujita, M., (2020). Selenium toxicity in plants and environment: Biogeochemistry and remediation possibilities. *Plants, 9*(12), 1711.

16. He, Y., Xiang, Y., Zhou, Y., Yang, Y., Zhang, J., Huang, H., & Tang, L., (2018). Selenium contamination, consequences, and remediation techniques in water and soils: A review. *Environmental Research, 164*, 288–301.

17. Hong, S. H., Lyonga, F. N., Kang, J. K., Seo, E. J., Lee, C. G., Jeong, S., & Park, S. J., (2020). Synthesis of Fe-impregnated biochar from food waste for selenium (VI) removal from aqueous solution through adsorption: Process optimization and assessment. *Chemosphere, 252*, 126475.

18. Kaur, P., Monga, D., & Singh, B., (2021). Biosensors for the detection of selenium in environment. *Selenium Contamination in Water*, 169–180.

19. Kunhikrishnan, A., Choppala, G., Seshadri, B., Park, J. H., Mbene, K., Yan, Y., & Bolan, N. S., (2017). Biotransformation of heavy metal (loid) s in relation to the remediation of contaminated soils. In: *Handbook of Metal-Microbe Interactions and Bioremediation* (pp. 67–86). CRC Press.

20. Lampis, S., Zonaro, E., Bertolini, C., Bernardi, P., Butler, C. S., & Vallini, G., (2014). Delayed formation of zero-valent selenium nanoparticles by Bacillus mycoides SeITE01 as a consequence of selenite reduction under aerobic conditions. *Microbial Cell Factories, 13*(1), 1–14.

21. Lemaire, J., Bustamante, P., Mangione, R., Marquis, O., Churlaud, C., Brault-Favrou, M., & Brischoux, F., (2021). Lead, mercury, and selenium alter physiological functions in wild caimans (*Caiman crocodilus*). *Environmental Pollution*, 117549.

22. Lenz, M., & Lens, P. N., (2009). The essential toxin: The changing perception of selenium in environmental sciences. *Science of the Total Environment, 407*(12), 3620–3633.

23. Ojeda, J. J., Merroun, M. L., Tugarova, A. V., Lampis, S., Kamnev, A. A., & Gardiner, P. H., (2020). Developments in the study and applications of bacterial transformations of selenium species. *Critical Reviews in Biotechnology, 40*(8), 1250–1264.

24. Okonji, S. O., Dominic, J. A., Pernitsky, D., & Achari, G., (2020). Removal and recovery of selenium species from wastewater: Adsorption kinetics and co-precipitation mechanisms. *Journal of Water Process Engineering, 38*, 101666.

25. Papp, L. V., Holmgren, A., & Khanna, K. K., (2010). Selenium and selenoproteins in health and disease. *Antioxidants and Redox Signaling, 12*(7), 793–795.

26. Rashid, M. M., (2018). *The Investigation of Photocatalytic and Adsorptive Properties of Humic Acid Grafted Magnetite Nanoparticles for the Remediation of Arsenic, Selenium, and Phosphorous from Water*, *15*(7), 37–51.

27. Raymond, L. J., & Ralston, N. V., (2020). Mercury: Selenium interactions and health implications. *NeuroToxicology, 81*, 294.

28. Sabuda, M. C., Rosenfeld, C. E., DeJournett, T. D., Schroeder, K., Wuolo-Journey, K., & Santelli, C. M., (2020). Fungal bioremediation of selenium-contaminated industrial and municipal wastewaters. *Frontiers in Microbiology, 11*, 2105.

29. Singh, R., Singh, S., Parihar, P., Singh, V. P., & Prasad, S. M., (2015). Arsenic contamination, consequences, and remediation techniques: A review. *Ecotoxicology and Environmental Safety, 112*, 247–270.

30. Singh, S., Bashambu, L., Devi, P., & Kansal, S. K., (2021). Chemical methods for removal and treatment of selenium from water. *Selenium Contamination in Water*, 206–227.

31. Song, B., Tian, Z., van der Weijden, R. D., Buisman, C. J. N., & Weijma, J., (2021). High-rate biological selenate reduction in a sequencing batch reactor for recovery of hexagonal selenium. *Water Research, 193*, 116855.

32. Suazo-Hernández, J., Sepúlveda, P., Manquián-Cerda, K., Ramírez-Tagle, R., Rubio, M. A., Bolan, N., & Arancibia-Miranda, N., (2019). Synthesis and characterization of zeolite-based composites functionalized with nanoscale zero-valent iron for removing arsenic in the presence of selenium from water. *Journal of Hazardous Materials, 373*, 810–819.

33. Tanmoy, P. A. U. L., & Saha, N. C., (2019). Environmental arsenic and selenium contamination and approaches towards its bioremediation through the exploration of microbial adaptations: A review. *Pedosphere, 29*(5), 554–568.

34. Teng, Y., Wang, X., Li, L., Li, Z., & Luo, Y., (2015). Rhizobia and their bio-partners as novel drivers for functional remediation in contaminated soils. *Frontiers in Plant Science, 6*, 32.

35. Vogel, M., Fischer, S., Maffert, A., Hübner, R., Scheinost, A. C., Franzen, C., & Steudtner, R., (2018). Biotransformation and detoxification of selenite by microbial biogenesis of selenium-sulfur nanoparticles. *Journal of Hazardous Materials, 344*, 749–757.

36. Wadhwani, S. A., Shedbalkar, U. U., Singh, R., & Chopade, B. A., (2016). Biogenic selenium nanoparticles: Current status and future prospects. *Applied Microbiology and Biotechnology, 100*(6), 2555–2566.

37. Wang, X., Zhang, D., Qian, H., Liang, Y., Pan, X., & Gadd, G. M., (2018). Interactions between biogenic selenium nanoparticles and goethite colloids and consequence for remediation of elemental mercury contaminated groundwater. *Science of the Total Environment, 613*, 672–678.

38. Wei, J., Shen, B., Ye, G., Wen, X., Song, Y., Wang, J., & Meng, X., (2021). Selenium and arsenic removal from water using amine sorbent, competitive adsorption, and regeneration. *Environmental Pollution, 274*, 115866.

39. Yang, D. Y., Chen, Y. W., Gunn, J. M., & Belzile, N., (2008). Selenium and mercury in organisms: Interactions and mechanisms. *Environmental Reviews, 16*, 71–92.

40. Yu, X. Z., & Gu, J. D., (2013). Phyto-transport and assimilation of selenium. In: *Plant-Based Remediation Processes* (pp. 159–175). Springer, Berlin, Heidelberg.

41. Zhang, H., (2014). *Impacts of Selenium on the Biogeochemical Cycles of Mercury in Terrestrial Ecosystems in Mercury Mining Areas*. Springer Science & Business, *14*(2), 71–94.

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Selenium Contamination in Water

Selenium is pervasive in the environment, being delivered from both natural and anthropogenic sources. The chief arrivals of selenium into the ecosystem as an outcome of human exercises result from the burning of coal. Laborers in the metals business and health administrations, mechanics, and painters might be presented to more elevated levels of selenium than everybody else. For everyone, the essential openness pathways are food, water, and air. The overall extent of these openness pathways at risky waste destinations are not known. Despite the fact that selenium has been accounted for at perilous waste locales, investigation on explicit structures has not been performed. Selenates and selenites are water dissolvable and, in this manner, can be found in water sources. Salts of selenic and selenious acids are well on the way to be found in surface water and water contained in the soil. Selenium sulfides would not be required to be found all things considered in dangerous waste destinations, since they are typically produced for use in shampoos. Natural wellsprings of selenium incorporate the enduring of selenium-containing rocks to soils and volcanic emissions.

Surface waters can get selenium from the climate by the dry and wet statement, from connecting waters that may contain selenium, from surface spillover, and from subsurface seepage. Sewage treatment plants are another wellspring of selenium deliveries to water. Effluents from sewage treatment plants and petroleum treatment facilities seem, by all accounts, to be the significant wellsprings of selenium. The book makes reference to that roughly 50–76% of the absolute selenium in the effluents was selenite. This extent of selenite is higher than that found in regular estuary sources. The book specifies that around 150,000–460,000 tons of selenium each year are saved in coal fly debris. Selenium from fly debris settling lakes and perilous waste locales could arrive at surface water through spillover or could reach groundwater by means of filtering. The expulsion of selenium from water medium is complex and costly, due to the high wastewater volumes created, low release limits (even in µg/L), and the presence of Se(IV) and Se(VI) species. As administrative cutoff points are becoming stricter, selenium expulsion from wastewater has gotten increasingly testing. Around 18% of 3,000 faucet water tests had selenium content surpassing the Environmental Protection Agency principles. Drinking water principles additionally require selenium expulsion from surface and groundwaters. The selenium amounts in polluted wastewater should likewise be diminished to limit its effect on regular water assets or to be reused. Because of its high harmfulness, selenium is, as of now, delegated a destructive substance; be that as it may, these days, it is otherwise called a fundamental micronutrient. Lack of selenium may cause liver, muscle, and heart sicknesses, for example, the Kashin-Beck illness. Selenium can also be found in selenoproteins. As indicated by the book, the convergences of selenium that are found in modern effluents range somewhere between 0.1 and 20 mg/L. The water system of farming areas is just one of the pathways for selenium preparation and transport. There are additionally different factors like coal burning, silver, gold, coal, and phosphate mining, metal purifying, city landfills, and transport, refining, and usage of oil. The fundamental wellspring of selenium in mining activities is surface rock. Selenium species drain or relocate to the environment from the stone when it is exposed to water.

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ISBN 978-1-77469-281-3

9 781774 692813 00000

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