DOI: 10.5281/zenodo.10682403

CHAPTER 13

A Study on Heavy Metal Pollution in Water

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Received: 24 January, 2024; Accepted: 25 January, 2024

Abstract

Water is a vital natural resource that covers the majority of the earth's surface, with fresh waters and oceans accounting for 70%. However, fresh water bodies only account for 3%. The rapid increase in industry and urbanization, along with significant population expansion and agricultural practices, has led to a substantial increase in heavy metals pollution. This poses a significant danger to every aspects of the environment, especially water. HM pollution has detrimental effects on several aspects such as aquatic environment, soil, people, as well as flora and fauna. Need for cleanup of heavy metal pollution subsurface and surface water sources significantly increased in recent years. Moreover, the infiltration of perilous heavy metals enter in to the human body via food chains amplifies the urgency of this need, particularly in agricultural areas. In addition to typical ailments, regions where irrigation has used groundwater tainted with heavy metals also experience a range of neurological and cancer-related problems. Hence, it is crucial to thoroughly investigate the agricultural soil and water before commencing agricultural activities. Heavy metals may be released into water supplies via both natural and human activities. Several international organisations and agencies, such as the World Health Organization (WHO), Bureau of Indian Standard (BIS), United States Environmental Protection Agency, European Commission Environment, Australian Drinking Water Guidelines, and Norma Official Mexicana-(127-SSA1-1994), have established concentration limits to address the harmful effects of heavy metal contamination. The permitted limits set by the Bureau of Indian Standards (BIS). This requires doing exact sample and traceable tests in accordance with authorized standards and procedures.

Keywords: Heavy metal pollution, World Health Organization (WHO), Bureau of Indian Standard (BIS)

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Introduction

Concerns about measures and water pollution

In addition to sustaining life, water is crucial for the maintenance of healthy ecosystems, the production of food, and the generation of electricity. Furthermore, it has a vital role in connecting human existence with the environment, since it is the utmost essential factor for adapting to climatic changes. Water is crucial for sustained socioeconomic development. Hence, a sufficient and high-quality water supply is essential for agricultural, industrial, and home purposes. Nevertheless, water contamination has emerged as a crucial obstacle for the worldwide community in recent times. Water shortage, compounded by pollution, is causing significant water quantity and quality challenges globally. (Dikio 2010; Adesuyi et al. 2015).

Water pollution is mostly caused by human activities such as overexploitation of water resources, transportation, and uncontrolled discharge of industrial wastes into bodies of water. Untreated industrial and household wastewater may cause severe water contamination and have long-term effects on aquatic ecosystems synthetic colours, pigments, nitrates, and organic solvents are all components of the damaging water streams. These water streams also include nitrates. The extreme toxicity of heavy metals is a significant problem for environmentalists, chemists, and biologists. (Lone et al. 2017). Moreover, heavy metals are not biodegradable, thus they represent a significant hazard to aquatic and human life via buildup of biomolecules and biomagnifications, at very low levels found in various water sources.(McConnell, et al. 1993; Maekawa, T. 2003). Heavy metals are naturally occurring elements with large bulk density and atomic mass, making them denser than water. However, there is no unambiguous definition. Generally, they are characterised as species with a specific density of more than 5 g/cm3.(Moore et al.1984).

Heavy metals include arsenic, lead, chromium, mercury, cobalt cadmium, nickel, and selenium. Some heavy metals, including zinc and selenium, are essential micronutrients in particular, are very important for human health, as well as the health of animals and plants. (Salem et al.2000). Traces of specified levels of these metals are also required. In addition, it is well-established that the presence of heavy metals in water may lead to the development of abnormalities in fish, as shown by research conducted on wild populations. (Rashid et al.2019; Renberg, et al.1994).So these malformations serve as effective biomarkers that are easily accessible for the purpose of identifying heavy metal pollution in water. Nevertheless, when there is an overwhelming amount of heavy metals in aquatic sources, above acceptable thresholds, and their intake either via drinking water or the food chain, may be very perilous and perhaps lethal. (Suthar et al. 2009).

The improper treatment and release of wastewater from industrial and waste recycling businesses are major contributors to the pollution of surface water and groundwater with heavy metals. The excessive accumulation of heavy metals in water has significant detrimental impacts on aquatic animal species' ecological well-being and is primarily responsible for the decline in aquatic animal and plant populations, especially. (Sulaiman et al.2016). The specific fish species. Due to the potent neurotoxic properties of heavy metals, they disrupt the Interactions between fish species and their environment. These specific fish species are significant suppliers of protein for human consumption. They are also directly exposed to water polluted with heavy metals. Food chains serve as primary conduits for heavy metals to move human consumption of polluted groundwater and surface water as a result of contamination. (Scannell et al. 2007). Consequently, the effects on human health and aquatic life are regularly assessed by reputable organisations like the World Health Organisation (WHO 2004, 2007).

An example of this is when there is an excessive consumption of cadmium, which leads to harm in the kidneys and bones. Mercury, when consumed via fish in the food chain, may lead to neurological problems, especially in the developing foetus of pregnant women. (Yonglong et al.2015).Lead is known for its neurotoxic properties and has a substantial impact on reducing blood levels in youngsters when taken in excess of the recommended limits. Arsenic, specifically, originates from food chains, mostly via the consumption of rice and fish, and is known to induce cancer as well as harm to the liver and kidneys. (Yuan et al. 2014; Ahmed 2016).

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The succeeding sections provide a more detailed explanation of the detrimental consequences of water pollution caused by heavy metals. Hence, comprehending the present state of water pollution caused by heavy metals has significant environmental and economical significance. (Yahya et al. 2018).

This significantly aids in the development of comprehensive laws, regulations, and management procedures for companies that produce substantial amounts of effluents polluted with heavy metals. Furthermore, it may provide guidance to researchers and engineers in the design and development of advanced technologies for both wastewater treatment and the extraction of valuable heavy metals from waste streams. This will enhance water remediation efforts via a synergistic approach, enabling the recycling of treated water for various purposes and the recovery of heavy metal impurities as valuable resources. (Vikranthpridhvi, et al.2015). This chapter provides a thorough an investigation on the present level of pollution caused by heavy metals in water. The present chapter provides an up-to-date overview of this topic for readers engaged in many disciplines and domains, including ecologists. This will enhance water remediation procedures via a synergistic approach, benefiting both the treated water. (Rajbanshi, A. 2009). There are a lot of potential applications for the material, and the heavy metal contaminants may be turned into useful resources. This chapter delves deeply into the current situation of heavy metal contamination in water. The present chapter provides an up-to-date overview of this topic for readers engaged in many disciplines and domains, including ecologists.

The content includes several case studies that expose the detrimental effects of heavy metal pollution on local ecosystems inside water systems. Furthermore, this study extensively examines many crucial factors related to the presence of high levels of heavy metals in water sources. These factors include the detrimental impact on aquatic organisms, the transfer of heavy metals via the food chain, and the resulting consequences for human health. The analysis is based on a thorough investigation of relevant literature publications. This eventually contributes to the planning, execution, and improvement of treatment technologies and management approaches for the remediation of heavy metal pollution in water supplies.

Types of Water Pollutants

At this point in the twenty-first century, pollution of any form is a major problem all over the world. There has always been a lot of focus on pollutants, whether they are naturally occurring or man-made, because of their potential to negatively impact the ecosystem. The devastating effects of polluted water on ecosystems and the environment as a whole have made it a new worldwide danger. There are a number of ways to classify the various water pollutants. (Sheykhi et al. 2016).

Inorganic Contaminants

Sewage and industrial waste contribute organic molecules to the water body, and there are also high quantities of inorganic pollutants. According to (Singh et al. 2009), these chemicals don't break down naturally and stay in water systems for a long time.

Inorganic pollutants include a variety of substances such as pigments, alkalis, mineral acids, cyanides, fluorides, and heavy metals. Examples of these heavy metals include arsenic, mercury, lead, chromium, selenium, zinc, and others. (Paul, D. 2017). Once they settle into water, they become a nuisance. This can be the result of increased human activity, mechanical errors, or landfill runoff. According to some studies, inorganic pollutants are substances that are present in nature but have been altered by people to significantly increase their concentration in water sources. Anthropogenic activities, such as waste mining (especially of electronic waste), refining, and metallurgical processes release untreated discharge of waste effluents, which introduce inorganic contaminants into water sources. (Selvaraj et al. 2010). Such water contamination, particularly at greater quantities, poses a significant threat to human health and has catastrophic consequences for aquatic life and other creatures.

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Biological Contaminants

Such pollution in water sources is mostly caused by human acts. Biological contaminants provide the greatest threat to aquatic ecosystems. Bacteria, moulds, parasites, and household dust are all examples of biological pollutants. Several sources of these contaminants have been documented in studies. These include plant dusts, human and animal illnesses, microorganisms carried by humans and animals, and waste products from plants and soil. (Sartor et al. 1974).

Pollutants at High Temperature

The term "thermal pollution," which refers to changes in water temperature caused by human activity, has been used more often in recent years. Local water supplies may be thermally polluted due to the widespread using water for mechanical purposes as a coolant. The most common reason for this is the mixing of cold and hot water streams near the source of supply. (Sun et al. 2015). At the location where the dam's water release valve is located at its base, the coldest water is let out first. This is because, during the summer, the water on the dam surface becomes heated by the sun, and the water that is warmer is able to float more readily on the thickest and coldest water. When these streams meet the recipient's water supply, a temperature difference of almost 10 degrees Celsius is created.(Miara et al.2010).

Heavy Metal Pollution in Water

Water resources may also be affected by heavy metal pollution, which is classified as an inorganic contaminant. The presence of heavy metals in water is very dangerous and has received significant attention in recent years. While heavy metals often occur in small quantities in natural waterways, they are exceedingly poisonous even at extremely low levels. (Sheykhi, et al. 2016). The continual and fast industrialization has led to an increase in heavy metal pollution in water supplies, resulting in serious repercussions. Numerous laws and regulations have been implemented globally to monitor and regulate the contamination of heavy metals in water. (Georgieva 2018). The succeeding part provides the requirements for allowed levels of heavy metals in water sources, as well as a discussion of the principal causes of heavy metal pollution in water.

Accepted Thresholds for Heavy Metal Concentrations in Water

Heavy metals may be released into water supplies via both natural and human activities. Several international organization and agencies, such as the World Health Organization (WHO), Bureau of Indian Standard (BIS), United States Environmental Protection Agency, European Commission Environment, Australian Drinking Water Guidelines, and Norma Official Mexicana-(127-SSA1-1994), (Homans 2014).Have established concentration limits to address the negative consequences caused by heavy metal pollution. (Morais 2012).The permitted limits set by the Bureau of Indian Standards (BIS) for heavy metals in water and similar substances are provided in Table 1.

Table 1: The permissible level for heavy metals in drinking water as published by several organisations

Order	Heavy metal	Permissible in limits (mg /L)			
		Drinking water	Surface water	Public sewers	Irrigation water
1.	Arsenic	0.05	0.2	0.2	0.2
2.	Mercury	0.001	0.01	0.01	0.01
3.	Cadmium	0.01	2	1	--
4.	Chromium	0.05	0.01	2	--

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5.	Selenium	0.01	0.05	0.05	
6.	Lead	0.1	0.1	1	--
7.	Nickel	0.1	3	3	--
8.	Zinc	15	5	-	5

Methodology

Heavy metals pose a severe worldwide health risk due to their ability to accumulate in the body, defy cleansing mechanisms, and alter intracellular metabolic pathways. In India, the spiritual system also has the responsibility for Contamination of water. The primary bioremediation techniques, Due of their affordability and environmentally conscious attitude, they are used to extract toxic metals from water. Currently, the desalination technique is widely used procedure for desalination of sea water. (Kawaji et al. 2008)

The groundwater that has been polluted includes a variety of pollutants in addition to heavy metals. To produce potable water for human use, the polluted water may be purified by a three-step remediation procedure. (Talabi et al.2019)The first stage involves the main removal of organic matter and suspended solids from wastewater by a range of techniques such as screening, filtering, centrifugal, sedimentary, and gravity-based separation processes. Afterwards, the water goes through an additional biological treatment process to get rid of organic and inorganic contaminants, both soluble and insoluble. Separation techniques for the second stage of treatment are broadly classified as either aerobic or anaerobic. Important heavy metals, both soluble and insoluble, are removed at the third stage of water treatment. The third phase involves a range of chemical and physical techniques, such as oxidation and adsorption. (Tara et al.2020). Numerous review papers have explored approaches for addressing heavy metal contamination with water, "case studies" conducted to address major water pollution issues and their repair. This chapter briefly describes several methods for removing heavy metals, including oxidation/precipitation, ion exchange, coagulation, electrolysis, and adsorption.

Methods and procedures for decontaminating heavy metals

Membrane filtration/reverse osmosis

Recently, membrane filtration has gained popularity as a water treatment method. Membrane filtration involves two methods: adsorption and filtration. It is often used for organic, suspended solids, and inorganic contaminants. (Azimi, et al. 2017). It is mostly used to remove heavy metals from water. This approach relies on the size of residual contaminants. The processes of ultrafiltration, nanofiltration, and reverse osmosis methods are used to remove heavy metals from water. (Van Der Bruggen et al. 2012). The ultrafiltration technique uses a 5-20 nm permeable membrane to remove heavy metals, macromolecules, and suspended particles from polluted water. It only separates molecules with a molecular weight of 1000-100,000 da. Only low molecular weight solutes and nano-sized particles may be filtered. (Bolisetty et al. 2019). To address the drawbacks, the researcher used polymer-supported ultrafiltration for heavy metal removal from water, which is gaining popularity for removing water pollutants. (Fig. 1)

ISBN: 978-93-95369-85-5 |

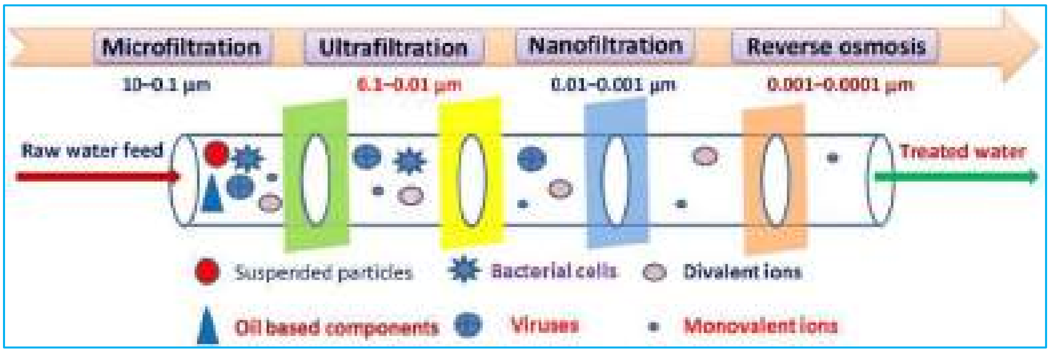

Fig. 1: Represents Schematic representation of membrane filtration process

Adsorption method

Adsorption is the preferred approach because to its ease of use, minimal sludge production, cheap cost, and many adsorbent options. Over the years, researchers have used nanomaterials, carbon compounds, alumina, and resins as adsorbents to remove heavy metals from water. (Singh et al. 2018; Singh et al. 2020). Activated carbon is often used to remove heavy metals from water, both organic and inorganic. Activated carbon is made from low-cost bio-based waste products, such as coconut husk, peanuts, and tree leaves.

Bioremediation

Bioremediation, also known as phytoremediation, involves using plants to remove hazardous metals and chemicals from air, soil, and water. The process has five steps: phytoextraction, phytoming, phytostabilization, rhizofiltration, and phytovolatilization. (Behera 2014) Researchers have recently found that Pteris vittata, a Vetiver grass, may remove harmful metals via phytoremediation.(Cherian et al. 2005). A Pollution of the water Phytoremediation is cost-effective and ecologically beneficial. However, Plants inhale hazardous metals, contaminate food crops, and ingest them. Toxic metals from polluted environmental sources (water, air, and soil) need longer time to eradicate.

Ion exchange

The ion exchange technique analyses wastewater treatment for producing drinkable water. In 1850, Thomas Way pioneered the ion exchange technique for water purification by passing an ammonium sulphate solution through soil. The ion exchange process effectively removes contaminants, including hazardous metals, and is used as a substitute for reverse osmosis (RO). (Alyuz et al.2009). Ion exchange is a chemical process that removes ionic contaminants from water using charged ions. This procedure removes contaminants from water via operations such as dealkalization, deionization, and disinfection. (Kurniawan et al. 2006).The ion exchange process removes hardness (such as calcium and magnesium ions) from water, resulting in soft water. This treatment technology uses synthetic resins to eliminate water pollutants like zeolites. (Zehra 2020).

Conclusions and Recommendations

Heavy metal pollution from industrialization, urbanisation, population increase, and agriculture poses a significant danger to the environment, especially water. Heavy metal pollution harms practically everything, including water, soil, people, animals, aquatic and plant life. In recent years, there has been a significant increase in the demand for heavy metal cleanup in both surface and groundwater. Agricultural areas have a higher need for harmful heavy metals since they enter the human body via food chains. Besides the traditional ailments, several neurological and cancer-related problems are also reported in such zones where irrigation entailed the use of heavy metal contaminated groundwater. Before beginning agricultural techniques, it's important to thoroughly

ISBN: 978-93-95369-85-5

examine the soil and water. Precise sampling and traceable tests should be performed in accordance with established standards and procedures.

When heavy metal pollution in water exceeds permitted levels, immediate action is required. Remediation procedures should be tailored to local resources and needs. To address heavy metal pollution in water, extensive data collection and database building are necessary. This includes integrating all anthropogenic causes that contribute to heavy metal release. Implementing heavy metal cleanup programmes without databases is tough, because the effect of these tactics on the ground is not visible. Thorough mapping of heavy metal pollution sources is crucial before implementing management strategies and treatment methods. Mapping sources at the micro-level/local size is crucial for water conservation efforts. Adopting a holistic approach is necessary for sustainable water development and heavy metal contamination control. Adsorption, a recent advancement in wastewater treatment, appears to be an effective method for eliminating heavy metals from water. This method not only removes heavy metals from water, but also allows for the recovery of adsorbed metals. Therefore, enhance waste-to-wealth initiatives. To obtain excellent remedial performance, many aspects must be considered. Critical aspects include determining the chemical composition and volume of heavy metal-contaminated water, selecting an appropriate adsorbent system, and managing adsorbent renewal and disposal. Safe drinking and portable water are crucial for survival, second only to oxygen. Keep an eye on water supplies throughout the world to see whether heavy metals are leaching in. Nevertheless, proper procedures and techniques for testing must be implemented. To provide accurate measurements, contaminated water must be sampled and analysed. A worldwide initiative is necessary to improve access to safe drinking and irrigation water. To conserve water supplies and prevent industrial emissions, rules and regulations must be updated or introduced in both developed and undeveloped countries.

The dangers of drinking water with heavy metals need to be made more widely known via educational initiatives. Particularly for low-income or rural families, it is critical to develop treatment systems that are both sustainable and financially feasible so that everyone has access to water of sufficient quality.

Compliance with ethical standards

Acknowledgments

We are grateful to Prof. Vidyavati, former Vice Chancellor of Kakatiya University, Warangal for her valuable suggestions and constant encouragement.

Disclosure of conflict of interest

The authors (Dr Raju Potharaju, and Prof M. Aruna) declare no conflict of interest.

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