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Assessment Of Heavy Metal Contamination (Cd, Pb, Cr, Zn, Cu, Ni, Mn) In Sewage Water In Sriganganagar

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Abstract

The study aimed to evaluate the levels of various heavy metals, such as iron, manganese, copper, and zinc, in vegetables grown with irrigation water sourced from different locations. The findings revealed a significant accumulation of heavy metals in vegetables watered with wastewater, resulting in confusion and frustration among farmers. Heavy metals like cadmium (Cd), lead (Pb), chromium (Cr), zinc (Zn), copper (Cu), nickel (Ni), and manganese (Mn) are likely present in the sewage water of Sriganganagar due to industrial activities such as textiles, leather processing, and chemical manufacturing, along with domestic and agricultural waste. This contamination poses serious health risks, including damage to the liver and kidneys, as well as reproductive problems. Although specific data for Sriganganagar is not provided, this kind of contamination is commonly observed in other industrialized regions of India. The presence of heavy metals in water, especially in industrialized areas, is a growing concern. Water is essential for life, and its contamination with heavy metals poses significant threats to human health. The study focuses on the levels of heavy metals in groundwater in India, such as arsenic (As), copper (Cu), cadmium (Cd), iron (Ir), lead (Pb), zinc (Zn), arsenic (As), chromium (Cr), and nickel (Ni), and their impact on human health. Three types of industrial effluents—iron processing industry (IR), battery industry (BT), and leather processing industry (LT)—were selected for the study. Parameters such as pH, biological oxygen demand (BOD), chemical oxygen demand (COD), and levels of heavy metals including zinc (Zn), lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), and cobalt (Co) were analyzed in the effluent samples. The pH values ranged from 1.86 to 11.63, indicating a highly variable and often extreme environment. BOD and COD data indicated that the samples were significantly polluted with organic and other chemical contaminants. One

sample from the iron processing industry showed high levels of zinc. Samples from the battery industry had elevated levels of lead.

Keywords: Groundwater, Heavy Metal Contamination, Human Health Effects, India.

Introduction

Water covers more than 70% of the Earth's surface and is very important for people to live and for economic activities. However, how useful water is depends on its quality and how much of it is available. Clean water is needed for everyday use, farming, and industries. But more and more people are having trouble getting clean water because of pollution. Different types of pollutants like organic waste, chemicals, harmful germs, and heavy metals make water unsafe to use and harm the environment. Some heavy metals like cadmium, lead, mercury, and arsenic are especially dangerous because they don't break down easily, are very harmful, and build up in living things over time, which can hurt both nature and human health[1]. These pollutants come from different sources, including places like factories that release waste into water and from spread-out sources like farm runoff. As cities and industries grow, more polluted water is being dumped into rivers, lakes, and other water bodies every day. This polluted water, full of heavy metals and other harmful substances, is damaging fish, plants, and people's health. It’s really important to manage wastewater properly to save water and stop these harmful effects[1]. Heavy metals are dense and have high weight. Some, like copper, zinc, and nickel, are needed in small amounts for living things, but others like lead, mercury, and cadmium are completely harmful. Many of these heavy metals come from industries such as metal processing, mining, and battery production. These metals don't break down and build up in soil, water, and living things, causing big environmental and health problems. Water used in farming, which often has a lot of organic matter and dirt, adds to heavy metal pollution if it’s not treated properly[2]. Heavy metals like cadmium, nickel, copper, and mercury harm soil and plant health. They make it harder for plants to take in nutrients, reduce their ability to make food through photosynthesis, and affect how plants grow and function. Cadmium and nickel are especially harmful, reducing how well seeds grow, while copper and mercury lower the plants' ability to make food, leading to slower growth. Cadmium is a very toxic metal. When it gets into the body, it can cause serious health problems. In 2022, it was found that nickel has both harmful and useful properties. Too much heavy metal in soil can cause plants to turn yellow, damage their enzymes, and mess up their basic processes, affecting how plants grow and develop. If plants grow in polluted water, the heavy metals can

move into the food we eat. Animals and humans who eat these plants may then take in the heavy metals, which can build up in the food chain[2]. This can cause serious health issues like damage to organs, delays in growth, and long-term damage to the environment. It's very important to stop heavy metals from getting into farming areas to protect plants, make sure food is safe, and keep the environment healthy. Heavy metals are a group of elements found in nature in very small amounts. When these metals are present in high levels, they can be harmful to living things. The way trace metals behave in groundwater is complex and depends on where the water comes from and the chemical and biological processes happening in the environment (WHO, 1993) [3]. Some metals are necessary for the body to work properly, while others are not. Most metals are important for the growth, development, and health of living organisms. However, the amount and quality of groundwater can change because of human activities. This can make groundwater unsafe for drinking and harm natural areas. It is a big scientific challenge to understand how these changes affect underground water systems and predict future changes. Groundwater is used for many things like industry, agriculture, and everyday use around the world. Human activities like farming and daily life release a lot of pollutants into the environment. In India, people use ponds, rivers, and groundwater for daily and farming purposes. The main sources of water are rain, rivers, lakes, and groundwater from wells and boreholes. In recent years, the growth of industry, technology, and population has put more pressure on land and water resources. This has caused local groundwater quality to get worse[4]. Wastes from cities and industries, fertilizers, pesticides, and other chemicals have gone into the ground and polluted some aquifers. Other pollution problems come from leaking sewers and improperly built septic tanks and landfills. In some coastal areas, heavy pumping of fresh groundwater has caused saltwater to mix with freshwater. As cities grow, water pollution problems become more serious, leading to big ecological and environmental issues. Industrial activities that don’t care about the environment cause water and air pollution, leading to soil damage and large environmental problems like acid rain, global warming, and ozone layer depletion. Water temperature affects the metabolic and life processes of aquatic organisms[1]. Groundwater supply depends a lot on rainfall and how much water seeps into the ground. The quality of the soil is also an important factor. Heavy metals play a role in the normal functioning of the human body. An imbalance in one of these metals can cause problems for the body. Heavy metals come into water systems from both natural and human sources[5]. These metals are dense, found in very small amounts, but are very toxic and can build up over

time, which is why they are called trace metals. The main sources of heavy metals from human activity include waste from mining, metal processing plants, and runoff from homes and streets. Many of these metals are highly toxic to humans, such as manganese, nickel, arsenic, tin, cadmium, lead, mercury. Having these metals in water at levels higher than background levels is not good. Some heavy metals like manganese, nickel, arsenic, tin, cadmium, lead, and mercury are harmful to the aquatic environment and human health. Humans have evolved in the presence of metals and can handle varying levels of essential and non-essential metals. Metals from food and the environment end up in organs like the brain, liver, and kidneys. The effects inside the body depend on how these metals affect these systems. Extra metals in the body are usually removed through urine and feces or build up in different tissues[5].

Waste water From Domestic Wastewater

Household wastewater contains significant traces of metals from metabolic waste, corrosion of water pipes like copper (Cu), lead (Pb), zinc (Zn), and cadmium (Cd), as well as from household products such as detergents, which may contain iron (Fe), manganese (Mn), chromium (Cr), nickel (Ni), cobalt (Co), arsenic (As), and mercury (Hg). Wastewater treatment processes typically remove less than 50% of the metals present in the influent, resulting in effluents that still carry a high load of metals. Additionally, sludge generated during wastewater treatment is also rich in these metals. Domestic wastewater and sludge from domestic and industrial sources are the main anthropogenic contributors to metal pollution, particularly cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), and mercury (Hg) [6].

Survey Area

Ganganagar District is situated at the northernmost part of Rajasthan and covers an area of approximately 11,154.66 km². It is bordered by Hanumangarh district in Rajasthan. The region experiences a dry climate with hot summers and cold winters. The Southwest Monsoon season in Ganganagar spans from June to mid-September, followed by a dry period until the end of November. Major crops grown in the area include wheat, mustard, cotton, bajra, sugarcane, gram, and others. The soil in this region is characterized by the presence of a calcareous layer, found at depths of 75-100 cm. The soil is deep and gently drained, with slow permeability and moderate water retention capacity. The soil's natural fertility is generally poor. The common soil types found here are lehm and sandy loam. Four primary crops Cyamopsis tetragonoloba, Vigna radiata, Pennisetum glaucum, and Gossypium arboretum were selected for studies on heavy metal

contamination[7]. The choice of these crops was based on their cultivation in the region. A study examining heavy metal contamination in the soils of Rajasthan's Sri Ganganagar district, India, includes assessments of heavy metal concentrations in both rural and urban areas. This study likely involves testing for levels of Lead (Pb), Iron (Fe), Manganese (Mn), Zinc (Zn), and Copper (Cu) [1]. The aim of the study is to determine if there are significant differences in heavy metal levels between rural and urban environments, influenced by factors such as industrial activity, agricultural practices, and proximity to urban centers. The findings are crucial for understanding the potential health and environmental risks associated with heavy metal pollution in this region. Heavy metals are persistent environmental pollutants[7]. Once they enter the soil, they are difficult to remove and significantly alter the soil's physicochemical properties, resisting biodegradation or pyrolysis. These metals can exceed certain thresholds, causing toxic effects on soil microorganisms, plants, and animals, which can disrupt soil enzymes and microbial activity. Plants absorb heavy metals through their roots and leaves, a process influenced by plant species and their intrinsic defenses against toxicity. A significant reduction in photosynthetic activity in plants poisoned by heavy metals leads to lower biomass production. Additionally, vegetable physiological and biochemical processes such as respiration, metabolism, transcription, translation, and the cell cycle are affected[8]. The toxicity of different heavy metals varies, and their combined effects can be cumulative. For example, the combined effects of Cu and Cd in barley plants can result in reduced root and stem growth. Heavy metals bioaccumulate in the ecosystem's food chain, leading to significant accumulation in the human body through skin contact, food, air, and water. Regular exposure can interfere with growth and weaken the immune system, posing a direct or indirect threat to human health. Furthermore, heavy metals can enter the human body through the skin and air, and are naturally mutagenic and carcinogenic. In severe cases, they can cause health problems related to the cardiovascular, respiratory, skin, reproductive, and immune systems. Urban soil plays a critical role in urban ecosystems, and its quality significantly impacts the quality of life and health of residents. Urban soil inherits certain characteristics from natural soils but differs widely due to dense human activity. These soils have unpredictable stratification, low permeability, low moisture content, and high trace element content[1]. They serve as key repositories for heavy metals and other contaminants. Due to limited environmental transport capacity and self-regulation, the rapid expansion of urban areas leads to an influx of heavy metals from accelerated urbanization and industrialization. This influx burdens

urban ecosystems and biogeochemical cycles, causing environmental issues such as soil function deterioration, structural changes, and property alterations. Heavy metals enter urban soils through two major sources: natural sources and anthropogenic activities. Natural sources primarily include parent materials and soil formation processes. However, anthropogenic activities such as fossil fuel burning, waste burning, traffic emissions, metal smelting, and intensive agricultural practices significantly affect the metal content in urban soils. Although urban soils are rarely used for agricultural purposes, comprehensive production and mulch use can contribute to pollution, especially in agricultural activities. Heavy metals accumulate in the soil, entering the human body through inhalation, skin contact, or absorption[7]. This poses a significant risk to the health and well-being of urban residents, particularly children. Although areas such as parks and residential zones are not typically used for food cultivation, they still serve as important points of transmission for heavy metals in the human body. Investigating the distribution of heavy metals in urban soils is essential to ensuring human health by preventing prolonged exposure to contaminated environments[1].

Causes Of Contamination

Industrial waste:

Facilities involved in leather tanning, textile manufacturing, steel, and chemical industries are major sources of heavy metals like chromium, lead, and cadmium[9].

Domestic waste:

Everyday household products and waste can contribute to heavy metal contamination in sewage.

Agricultural runoff:

Use of fertilizers and pesticides can lead to heavy metals entering the water supply.

Health impacts:

Liver and kidney damage:

Exposure to high levels of heavy metals can cause serious damage to these organs.

Reproductive problems:

Heavy metals can negatively impact the reproductive system[1].

Cancer risk:

Some heavy metals, such as chromium, are associated with an increased risk of cancer.

Other Issues:

Health problems can also include gastrointestinal and skin issues, as well as mental disorders.

What can be done:

Monitoring and testing:

Regular testing of sewage and nearby groundwater is crucial to understand the extent of contamination.

Wastewater treatment:

Implementing effective treatment methods to remove heavy metals before releasing the water is essential. This can include both traditional and biological methods.

Source Control

The primary source of the problem, such as industrial discharge, needs to be controlled through stricter regulations and improved industrial practices[10].

Heavy Metals

Different types of water pollutants and how they affect the environment and people's health. This study looked at several traditional water pollutants, including nutrients like nitrate (NO3) and phosphate (PO4), organic pollutants such as POPs, EDS, and pesticides, halogens like chlorine (Cl), bromine (Br), and fluorine (F), microbial pollutants, and heavy metals like manganese (Mn), iron (Fe), copper (Cu), aluminum (Al), zinc (Zn), lead (Pb), chromium (Cr), nickel (Ni), cadmium (Cd), and mercury (Hg). Cadmium is very dangerous even in small amounts[7].

It can cause kidney problems, lung issues, bone issues, high blood pressure, and other health problems. Cadmium comes from industries like metal refining, battery making, pipe production, and painting. Even though emissions are managed in developed countries, it still causes health issues, especially for workers in developing countries. When cadmium gets into water, it can stay there for years and move through the food chain, harming other living things. Other sources include food and smoking[8]. Cadmium can hurt the liver and kidneys and also affects some fish. In most places, cadmium levels are very low, below 0.003 mg/L, except for three areas: IR7 (0.003 mg/L), LT2 (0.020 mg/L), and LT1 (0.004 mg/L). Cobalt levels are also below the detection limit in all samples.\

Nickel is important for some bacteria and helps in their processes, but too much can be harmful. Some bacteria like E. coli and H. pylori have ways to handle nickel to avoid its effects. Long exposure to nickel can cause breathing issues, cancer, and lung problems. Nickel builds up in water mainly from air pollution, like from power plants and incinerators, which settle in the soil

and run off into water. It can also get into water through poorly treated waste. A little nickel is useful, but too much is bad for lungs, kidneys, and skin. In most samples, nickel levels are below the limit, but a few samples had higher levels: LT2 (0.12 mg/L), IR4 (0.09 mg/L), IR1 (0.07 mg/L), and LT1 (0.06 mg/L). No sample had more than 0.12 mg/L. Cobalt can cause health problems like asthma, heart trouble, thyroid issues, and liver damage. It can be removed from water using different methods. The safe amount in drinking water is 2 micrograms per liter. For livestock and irrigation, the limits are higher: 1 mg/L and 0.05 mg/L, respectively[9].

Chromium is harmful to the environment, causing soil and water pollution, affecting plants and aquatic life, and harming human health. High levels of chromium can lead to serious health issues. The highest chromium level was found in LT1 at 2.15 mg/L. Other samples had lower levels: LT2 (1.72 mg/L), IR1 (0.27 mg/L), IR7 (0.18 mg/L), and IR4 (0.07 mg/L). In other areas, chromium levels were below the detection limit. Zinc is used in many products like paint, rubber, and cosmetics.

Industries can release zinc into the environment if wastewater is not properly treated. Zinc particles can settle in soil and mix with groundwater. Zinc is important for balancing copper levels, healing wounds, cell growth, immunity, and reproductive health. It also helps prevent skin aging. But too much zinc can cause kidney issues, blood in urine, vomiting, and anemia. High zinc levels can slow down growth and development. Symptoms of zinc poisoning include diarrhea, vomiting, and problems with the kidneys and liver[10].

Lead is a very dangerous heavy metal.It is found naturally in small amounts in the Earth's crust. Sources include mining, smelting, refining, old gasoline, and industries like battery production, paint, ceramics, and glass. Lead is very harmful to children and pregnant women, causing miscarriage, stillbirth, and premature birth. It can also lead to stomach problems, liver and kidney damage, high blood pressure, and neurological issues. In children, it harms the nervous system. Lead also causes anemia, tiredness, paralysis, and shaking. Inhaling lead can lead to problems like low blood oxygen, kidney and joint problems, heart issues, and brain damage[8-9].

Heavy Metal Analysis

- **Metal Selection:** The study is probably going to focus on metals like Lead (Pb), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni), and Zinc (Zn).

- **Analytical Methods:** They will use techniques such as Inductively Coupled Plasma Mass Spectrometry (ICP-MS) or Atomic Absorption Spectroscopy (AAS) to measure the amounts of these metals[8].

Conclusion

India is continuously progressing towards its development. The country's development is largely driven by its industries and mining sectors. Various types of heavy metals, some of which are highly toxic, are rapidly polluting groundwater through processes like leaching. These metals are entering groundwater through industrial areas, population growth, quarry residues, metal wastes, leaded gasoline, paint, and other sources, causing confusion and frustration among people. In summary, the study on heavy metals in the soil of Sri Ganganagar provides valuable insights into the extent of contamination, possible sources, and the associated health and environmental risks. This data can aid in formulating strategies to manage and reduce heavy metal contamination in the area. The main objective of this study was to evaluate the concentration of various heavy metals in the soil, water, and frequently grown plants in Sri Ganganagar. The issue of heavy metal contamination in urban soil environments is complex and necessitates comprehensive, proactive, and integrated approaches for management, assessment, and remediation.

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