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A REVIEW OF STUDY ON HEAVY METAL CONCENTRATIONS IN SOURCE OF WATER IN VIETNAM

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ABSTRACT: This paper reviews the heavy metal concentrations of water resources in Vietnam. Concentrations of heavy metals such as As, Fe, and Mn in ground water from the Red River and Mekong River Deltas were exceed than WHO drinking water guidelines, putting at risk the millions of Vietnamese people relying on groundwater in these regions as sources of drinking water. This situation suggests solution for drinking water suppliers together with efficient water treatment technologies for groundwater or alternative drinking watersources such as surface water or tap water. Vietnam has an expanding population and growing economy, and is undergoing rapid industrialization and urbanization. It is of the utmost importance that good strategies be developed for the management of safe drinking water for both public and private supply, in the cities as well as the countryside. Educating residents of rural areas to understand the effects of contaminated drinking water on their health is essential. A long-term water quality monitoring program with more frequent testing should also be considered. In Vietnam, groundwater is obtained primarily from tubewells, which have high concentrations of pollutants such as As, Fe, Mn, and NH_4^+. In the areas where groundwater tests were conducted, arsenic levels ranged from 0.1– 3050 μg/L, which substantially exceed the standard of 10 μg/L which has been established by the WHO. Contamination sources are distributed over a large area from the Red River Delta in the north to the Mekong River Delta in the south, putting as many as ten million people at risk of adverse health effects. Levels of arsenic and iron in sediment are strongly correlated, which indicate that the presence of arsenic in groundwater results from the reduction of arsenic bound to iron oxyhydroxides. It is important to raise awareness of these issues among the Vietnamese public by disseminating information about the negative effects of contaminated drinking water, as well as carrying out long-term research projects to identify other sources of contamination and improving water treatment technology and water management capabilities.

Key words: Vietnam, heavy metals, surface water and ground water.

INTRODUCTION

Vietnam is a developing country located in Southeast Asia with an area of 329.566 km^2, which is shown in Fig. 1 **(Moglia *et al*., 2012).**

With a population of 90 million in 2011, it is the 13th most populous country in the world **(Berg *et al*., 2001).** Seventy percent of the population lives in rural areas, concentrated in the two main agricultural regions of the Red River Delta and Mekong River Delta. Between 2000 and 2010, average daily water consumption in Vietnam increased from 881,100 to 1,079,350 m^3 **(Moglia *et al*., 2012).**

Rapid industrialization and economic growth have led to a massive population shift from the countryside to the cities, creating increased strainon natural resources and the environment.

The primary sources of water pollution are untreated municipal and industrial wastewater **(Chau *et al*., 2015).**

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Additionally, climate change and global warming may also affect the quality and amount of rainfall, groundwater, and surface water. It is therefore urgent to concentrate on environmental protection and the management of natural resources in order to have transition toward sustainable development. There is considerable concern about safe drinking water among the Vietnamese public **(McArthur *et al*., 2012).**

The exploitation of groundwater for domestic use in Vietnam began roughly 100 years ago with the construction of wells operated by hand pumps. The consumption of polluted groundwater has considerable negative health consequences and can cause serious illnesses of various major organs **(WHO, 2015).**

Many regions of the world are faced with diminished water resources **(Moglia *et al*., 2012).**

This is due to multiple factors such as decreased water supplies, the contamination and overuse of surface and groundwater, and extended periods of low precipitation. From 1950 to the 1990s, a 100% increase in the global population, combined with declining quantities of freshwater, resulted in a substantial drop in the per capita availability of water resources. In addition, as much as 90% of wastewater is released into the environment untreated, exacting a heavy toll on public health **(WHO, 2015).**

The presence of naturally-occurring sediments in drinking water may also introduce toxic substances such as heavy metals. Each year, there are approximately four billion cases of diarrhea, causing 1.8 million fatalities, primarily of children. The overwhelming majority of these cases result from contaminated drinking water, unsanitary conditions, and deficient hygienic practices **(Thuy *et al*., 2015).**

Environmental pollution is an important issue these days, mounting every day with population growth and rapid industrialization, which is a great challenge posed by pollutants **(Yongfeng *et al*., 2017).**

Clean water, fresh air, and a pristine environment are becoming rare amenities across Asia. Over the past 50 years, the growing human population and intensifying industrialization and agricultural development have profoundly altered natural ecosystems and water quality, challenges which might be exacerbated by climate change in the region, although the overall impact of climate change on water quantity and quality will be marginal compared to socioeconomic changes, even by 2100 **(Thuy *et al*., 2015).**

Asia is no exception; as a result, 40% of the global death toll due to unsafe or inadequate supply of water, sanitation, and hygiene occurs in Asia (**WHO, 2015).**

With many rivers still in good condition, there are opportunities to prevent pollution and begin restoration. However, severe organic pollution is already affecting around one in seven rivers across Latin America, Africa and Asia. This poses a growing risk to public health, food security and the economy, while cultivating inequality by predominantly affecting the poor, women and children Programme (UNEP).

Due to climate change, two-thirds of mankind will face water scarcity by 2025, while by 2050, global food production must increase by at least 50% to feed 9 billion people. To overcome water scarcity, 15 million m^3/day of untreated wastewater is used globally for crop irrigation, polluting the soil with pathogens, heavy metals and excess salts. Since 10% of the global population consumes food from crops irrigated with wastewater, pathogens transmitted through the food chain cause diseases especially in young children and women **(Agoro *et al*., 2020).**

A shortage of fresh water is one of the most pressing environmental problems impeding sustainable development of the country. We now live against a permanent background of water-related disasters, from disappearing lakes in Central Asia to submerging islands in the Pacific. In an increasing number of locations around the world, rainfall is either too little or too great, or insufficiently reliable. In the coming years, a city will in all likelihood run out of water. Another will suffer a flood so catastrophic that it is abandoned.

Huge volumes of wastewater are generated daily in households, industries and agriculture. The volume of wastewater accounts for 50–80% of the domestic household water uses and the global wastewater discharge was estimated at

400 billion m^3/year, polluting approximately 5500 billion m^3 of water/year, as reported previously. Wastewater usually consists of 99% water and 1% suspended, colloidal and dissolved solids. It is well known that wastewater, depending on its source, is loaded with pollutants such as organic matter, suspended solids, nutrients (mainly nitrogen and phosphorus), heavy metals, emerging contaminants (antibiotics, hormones, personal care products, pesticides, polycyclic aromatic hydrocarbons, phenolic compounds, volatile organic compounds, antibiotic resistant bacteria and genes) and pathogenic microorganisms (bacteria, viruses, protozoans and parasitic worms) **(Nguyen *et al*., 2020).**

MATERIALS AND METHODS

The study is based on general historical, objective and description and analytical research principles. Applying these methods in the research enables to consider scientific knowledge as an integral system in which each previous approach indirectly or directly influenced the next one. All this together made it possible to compile a systematic series of scientific and theoretical calculations on the given issue. The views of authors are discussed regardless of ethnocultural preferences and political inclinations, which necessitates a thorough comparison of facts and phenomena in aggregate, that is, a comprehensive study of the problem. In addition, a systematic approach, which takes into account both the features of the research objects themselves and the factors that determine these features, is used in the paper. Such approaches allow to identify not only gaps in the studied subject, but also some particular aspects of the problem that might not have come to the scholars' attention for one reason or another. In general, this gives the opportunity to objectively compare these aspects and, on their basis, determine the prospects for further research **(Alimbaev*et al*., 2021)**.

Water Resources in Vietnam

The red river delta

Extending southeast from the national capital, Hanoi (population 11 million), the Red River Delta has an area of 169,000 km^2. It has a tropical monsoon climate with a rainy season extending from May to September and a dry season from October to April. Rural residents have switched from using surface water or water from shallow dug wells to using family tube wells from Holocene aquifer and Pleistocene aquifer **(Berg *et al*., 2001)** as their primary sources of drinking water. The removal of groundwater from the Pleistocene aquifer causes water to flow down from the Holocene aquifer **(Postma *et al*., 2007 and Nguyen *et al*., 2020).**

A water-permeable layer of clay several meters thick separates the Holocene and Pleistocene sediments, allowing water to flow between the two aquifers **(Smedle and Kinniburgh *et al*., 2002).** Table 1 shows the arsenic contamination in the aquifers in Hanoi **(Berg *et al*., 2001).**

Groundwater in Hanoi and its surrounding region is contaminated by high arsenic concentrations in the Holocene and Pleistocene aquifers, which is shown in Fig. 1. This issue raises the question as to whether arsenic mobilization is anthropogenic **(Thuy *et al*., 2015).**

Arsenic levels exceeded the current WHO standard of 10 μg/L in as many as 72% of the tubewells included in the study**(Agusa *et al*., 2006),** although there was a substantial degree of variation between different areas with concentrations ranging from 0.1 to 3050 μg/L **(Berg *et al*., 2007; Berg *et al*., 2008; Larsen *et al*., 2008; Eiche *et al*., 2008; Nguyen *et al*., 2009; Agusa *et al*., 2009; Postma *et al*., 2010 and Editorial, 2010)** and an average arsenic concentration from 159 to 430 μg/L **(Berg *et al*., 2001),** respectively. The sources of contamination are distributed over a large area in Red River Delta. Fig. 1 showed the arsenic contamination in groundwater from the private tubewells **(Berg *et al*., 2001).**

Samples of groundwater taken from Hanoi's eight water treatment plants revealed arsenic concentrations of 240–320 μg/L in three of the plants and 37–82 μg/L in the other five **(Berg *et al*., 2001).** Of the 29 tap water samples collected at individual homes (Fig. 1b), 27 had arsenic levels ranging from 7 to 82 μg/L with a mean concentration of 31 μg/L. Dissolved arsenic

Table 1. Arsenic contamination in the aquifers in Hanoi (Berg *et al*. 2001)

District	Number of sample	Concentration (µg/L)	Range (µg/L)
Dong Anh	48	31	1-220
Tu Liem	48	67	1-230
Giai Lam	55	127	2-3050
Thanh Tri	45	432	2-3010
All	196	159	1-3050

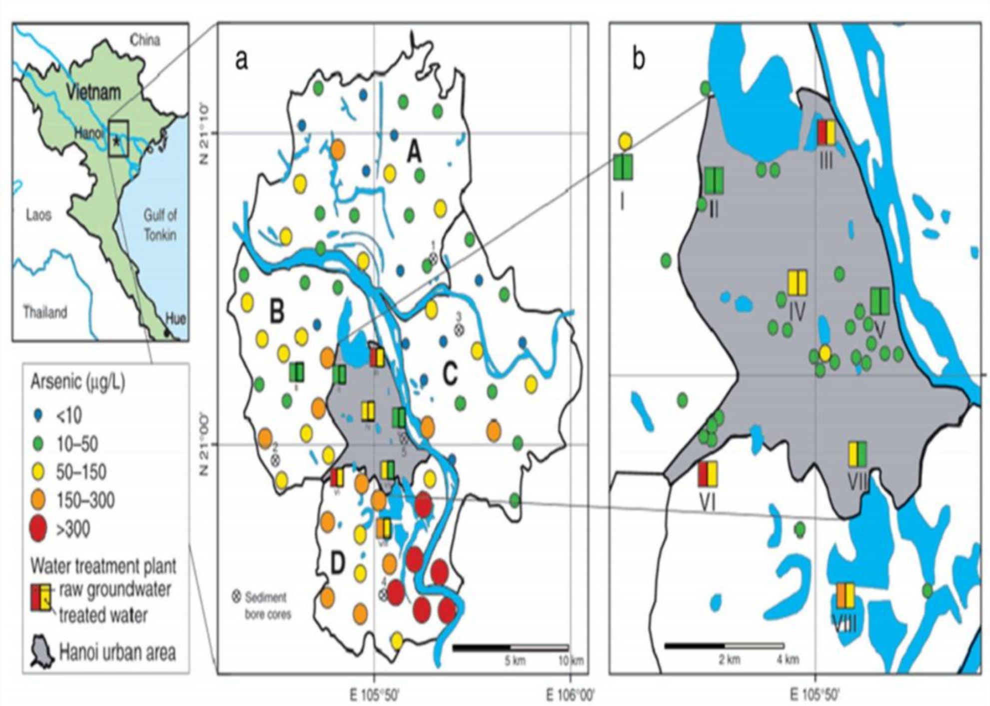

Fig. 1. Arsenic contamination in Hanoi. (a) In ground waters pumped from private tubewells. (b) In groundwater of the lower aquifer and treated water treatment plants (split rectangles) and tap water of supplied households (dots) (Berg *et al*., 2001).

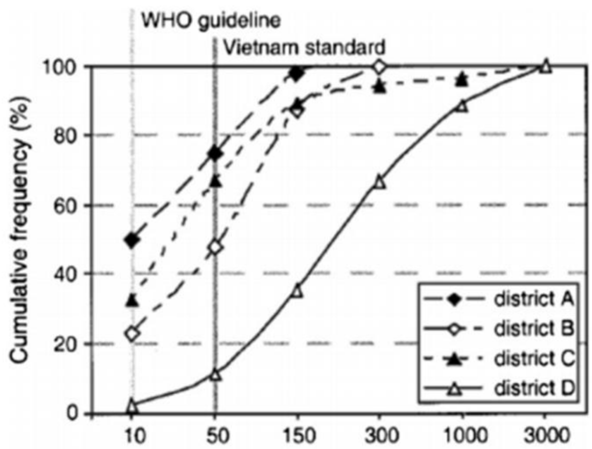

Fig. 2. Arsenic contamination in groundwater from the private tubewells (Berg *et al*., 2001)

may be binding to iron oxides on the inner surfaces of pipes leading to lower concentrations in the tap water **(Agusa *et al*. 2006).**

Given the high levels of arsenic found in water from the tubewells (48% above 50 μg/L, and 20% above 150 μg/L), several million people might be at risk of chronic arsenic poisoning **(Berg *et al*. 2008; Nguyen *et al*. 2009; Berg *et al*. 2007).**

The levels of contamination are comparable to Bangladesh and West Bengal, India; however, the population density is higher **(Smedle and Kinniburgh, 2002)**.

Arsenic is known to cause diseases of many major organ systems. Moreover, chronic arsenic exposure is correlated with an array of cancers (bladder, kidney, skin, and liver), where inorganic arsenic is more toxic than organic arsenicals **(Postma *et al*., 2010; Agusa *et al*., 2009 and Editorial, 2010).**

Because of naturally occurring organic matter in the sediments, the groundwater is anoxic and rich in iron. Arsenic concentrations from 25 to 91 μg/L were reduced by up to 80% by aeration and filtering through sand of arsenic concentration removed to discharge in the Red River delta **(Berg *et al*., 2007)** but 50% samples remained above the Vietnamese drinking water standard of 50 μg/L **(Berg *et al*. 2001).**

Sediment in the Red River Delta showed a correlation between arsenic andiron levels **(Berg *et al*., 2001).** It is possible that arsenic is bound to iron oxyhydroxides in the sediment and that the reduction of iron when it is dissolved in groundwater causes the arsenic to be released. Arsenic occurring in the sediment is most likely due to the deposition of arsenic- enriched oxyhydroxides which result from erosion and are transported by river currents. Brown to black-brown clay layers showed arsenic concentrations of 6–33 mg/kg with lower concentrations found in gray clay (2–12 mg/kg) and brown to gray sand (0.6–5 mg/kg) **(Berg *et al*., 2001).**

The primary form of arsenic found in the groundwater is As (III) with some As (V). Arsenic levels are closely related to levels of ammonium, which is released by the breakdown of organic matter. As (III)concentration peaks in the middle part of the aquifer with a distribution highly similar to that of ammonia and methane. This indicates that there may be a direct relationship between the release of as into the groundwater and the decomposition of organic material. The high alkalinity (up to 810 mg/L) and high nitrogen concentrations (10–48 mg N/L) of the groundwater strongly support this possibility **(Lawati *et al*., 2012; Minh *et al*., 2010 and Guilliot *et al*., 2008).**

Fe and Mn levels in groundwater were higher than those of alkaline earth metals such as Sr and Ba. Both Mn (500 mg/L) and Ba (700 mg/L) **(WHO, 2015)** were found in concentrations exceeding the WHO limit for drinking in some samples taken in Hanoi. Groundwater in Hanoi had an average Mn concentration exceeding 1000 mg/L. Seventy percent of the groundwater samples exceeded WHO drinking water guidelines for Mnand 12% exceeded those for Ba of 0.05 mg/L. Rainwater and surface waterin Hanoi also had low concentrations of As. Whine As, Mo, Ga, and Ba concentrations in groundwater showed a strong positive correlation, on opposite sides there was a negative correlation between concentrations of As and Pb and V. It is not yet clear what the reasons for these relationshipsbut they may be due to the subsurface geology and geochemistry of the Red River Delta. These results indicate that the use of groundwater in the Red River Delta may be exposing people not only to As but also to other metals like Mn and Ba **(Duong *et al*., 2003)**.

The mekong river delta

The Mekong River Delta is located in southern Vietnam and neighboring Cambodia, between the East Sea in the southeast and the Gulfof Thailand in the west. The Mekong River Delta consists of two main arteries (the Tien and Hau rivers), which branch into eight smaller rivers. The Mekong River Delta covers an area of 39,713 km^2 and contains delta sediments with characteristics similar to the Ganges Plain **(Hoang *et al*. 2010).**

Low-lying floodplains (2 m above sea level) with highly acidic sulfate soils comprise approximately 60% of the Mekong Delta. The local climate is tropical monsoonal, with average temperatures of 27–30 °C and a rainy season lasting from April to November. Local water resources include rainfall, surface water, and groundwater. Household shallow tube-wells access groundwater at a depth of 80 – 120 m **(Buschmann *et al*. 2008).**

The wells for water supply units and industrial uses access groundwater at a depth of 100–250 m, with 60% of wells accessing the Pleistocene aquifer. The main trends threatening the sustainability of groundwater in Mekong River Delta are declining groundwater levels and declining groundwater quality.

In a study of 460 wells in the Mekong River Delta, 26% of groundwater samples were found to exceed the WHO standard for drinking water of As (10 µg/L), 74% to exceed the standard for Mn (0.05 mg/L), and 50% that for Fe (0.3 mg/L). These data were shown in Table 2 **(Hoang *et al*., 2010).**

As levels ranged from 0.1 to 1351 µg/L, Fe concentrations from 0.01 to 38 mg/L, and Mn from 0.01 to 14 mg/L (**Hoang *et al*., 2010).** Arsenic was found in groundwater in wells less than 60–70 m deep in this region **(Buschmann *et al*., 2008).**

High Fe concentrations were found in the groundwater of Dong Thap, Kien Giang, and Long An provinces. High levels of As were found primarily in An Giang and Dong Thap provinces, with almost 50% of groundwater samples exceeding the WHO standard for As (10 µg/L). In addition, Mn concentrations exceeded the WHO standard of 0.05 mg/L in approximately 72% of samples from An Giang and 64% of samples from Dong Thap. Consumption of untreated groundwater in these two provinces could be exposing nearly two million people to the risk of chronic arsenic poisoning. In addition, the excessive intake of manganese can result in developmental problems in children.

Well depth and distance from the Mekong River are the primary factors determining the levels of As in groundwater, particularly in An Giang and Dong Thap. In An Giang, As levels in samples taken within 2 km of the Mekong River were nearly 1000% greater than those in samples taken at distances beyond 2 km. Samples taken within 10 km had average As concentrations of 64 µg/L, while samples taken at distances of more than 10 km had an average concentration of 8 µg/L. In An Giang, shallow wells (less than 60 m in depth) had as concentrations of 115 µg/L, while deeper wells had an average of only 19 µg/L. In Dong Thap, the equivalent figures were 63 µg/L for shallow wells (less than 70 m deep), and 3 µg/L for deeper wells. Another issue directly impacting the health of people relying on groundwater is urban runoff and pollution from municipal wastewater. Groundwater samples taken from wells in Can Tho, the largest urban area in the Mekong Delta contain high levels of total coliforms. It is therefore very important to analyze the quality of groundwater in the Mekong River Delta **(Nguyen *et al*. 2009).**

Sedimentation in the delta began with the deposition of silt carried by the river during the transition from the Pleistocene to the Holocene. The sediments in the Mekong River Delta are high in organic compounds which create anoxic conditions that may promote the reduction of dissolved iron (hydro)oxides and cause the release of arsenic. There is a need for increased awareness about the potential health impacts, especially the co-contamination involving multiple toxic elements. In the early Holocene, fluvial deposits displaced tidal deposits as the primary source of sedimentation, resulting in an outward movement of the coastline **(Berg *et al*. 2007).**

Groundwater in the lower Mekong Delta is highly saline with 4 g/L total dissolved solids (TDS). Shallow groundwater has been exploited as a drinking water source by the rural population as a replacement for surface water, which is contaminated by microbes. Other heavy metals such as Cd, Ni, Pb, and U are known to cause numerous health problems such as DNA damage, cancer, and disorders of the central nervous system. Because Ni, Pb, and Cd exceeded the WHO standard around ~1%, they are not likely tohave a significant public health impact. Uranium, however, can damage the kidneys and is also deposited on bone surfaces, where it emits alpha radiation and releases highly toxic decay products such as radon **(Berg *et al*. 2007).**

Comparison with other countries in the world, the as contamination in groundwater in

Table 2. The percentage of groundwater samples exceeding the WHO standard (Hoang *et al*., 2010).

Element	Percentage exceed the standard (%)			
	An Giang	Dong Thap	Kien Giang	Long An
As (10 µg/L)	43	38	24	12
Mn (0.05 Mg/L)	84	69	66	81
Fe (0.3 Mg/L)	13	54	55	71

Vietnam is quite high. It was estimated that around 150 million people in the world are probably affected by arsenic contamination in groundwater, especially in some Asian country as China, India, and Bangladesh **(Ali *et al*., 2012).**

As was found in shallow tubewells in the low-lying Mekong Delta at Prey Vêng province, Cambodia. The As contamination in wells at this region were 100 times higher than the WHO standard with maximum concentration of 1052 µg/L, nearly the same level with Arsenic contamination in Mekong delta in the south of Vietnam, while much lower compare with the north of Vietnam **(O'Neill *et al*., 2013).**

The Jianghan Plain in China has 87% of the groundwater in wells with depths of 5–230 m containing as level at 10–2330 µg/L **(Xiaoming *et al*., 2017).** In West Bengal of India, 48.1% of groundwater contains As above the WHO standard and 23.8% were above the Indian standard of 50 µg/L. The wells in Holocene sediments at 35–45 m depth in Beldanga contain high as concentrations at 10 – 4622 µg/L **(Harshad *et al*., 2017).**

A recent study in the Kolkata, India analyzed 262 groundwater samples in 144 wards and reported that 100 wards in alarming arsenic contamination. About 51 wards (35.4%) have arsenic concentration above the Indian standard of 50 µg/L while 49 wards got arsenic level 11–50 µg/L. As daily intake was estimated 0.95 µg/kg from drinking water and the cancer risk was 1425/106 **(Dipankar *et al*., 2017).**

Based on studies conducted in the Brahmaputra River, the As levels were found from 0.07–0.60 µg/L **(Runti *et al*., 2015).** As contamination in groundwater in the Nawalparasi District, Terai province in Nepal is a serious issue with the average concentration of 350 µg/L, and 98% groundwater exceeded the WHO standard of 10 µg/L. Higher As contamination at more than 400 µg/L in wells with depth at 18–22 and 50– 80 m. As concentration over 500 µg/L in shallower wells were detected at Patkhauli, Mahuawa, Thulokunwar, and Goini **(Akiko *et al*. 2014).**

In Mongolia, As concentrations are found in the range of 300– 553 µg/L at the SO_4^{2-} reduction stage, possibly results reduction of Fe oxide minerals from HS^- **(Yongfeng *et al*., 2017).**

High As levels was found in bedrock aquifer in western Quebec, Canada with more than half of the 59 bedrock wells exceed the WHO standard of 10 µg/L with As concentration ranges from 1.1–263.3 µg/L **(Raphaël *et al*., 2017).**

The As contamination in aquifers groundwater of Pliocene terrestrial layers is a significant issue in Sarkisla (Turkey) with concentration up to 345 µg/L and the average of 60.38 µg/L **(Celalettin *et al*., 2013).** As also was found in the range of 0–180 µg/L from 992 drinking water samples in households of New Hampshire, USA. Significantly arsenic in the domestic drilled bedrock wells more than water from municipal sources **(Qiang *et al*. 2009)**. **(Middleton *et al*. 2016)** reported that 5% private water supplies of 497 wells in Cornwall, South West England exceeded the WHO As standard of 10 µg/L.

Toxicity of Heavy Metals to Living Organisms

Toxic heavy metals like lead, cadmium, mercury, chromium, and arsenic have the maximum potential to cause harm on account of their extensive use, toxicity in elemental or combined forms, and widespread distribution in the environment. These five elements have a strong affinity for sulfur in the human body, and usually they bind via thiol groups (–SH) to enzymes responsible for controlling the speed of metabolic reactions. The resulting sulfur-metal bonds inhibit the proper functioning of the enzymes, which deteriorates human health and sometimes leads to death. Mercury and lead damage the central nervous system, and cadmium causes degenerative bone disease, whereas chromium (hexa-valent form) and arsenic are carcinogens that may induce cancer. Exposure to lead and mercury can cause the development of autoimmunity, which can result in joint diseases (rheumatoid arthritis), kidney diseases, circulatory and nervous system disorders, and fatal brain damage in humans. In children, exposure to lead and mercury causes reduced intelligence, impaired development, and an increased risk of cardiovascular disease. Cadmium can disrupt the endocrine system, damage fragile bones, and affect the regulation of calcium in biological systems and is known to be a mutagen and carcinogen. Hair loss, headaches, diarrhea, nausea, and vomiting in humans are caused by chromium **(Lu *et al*., 2017 and Abdel-Raouf *et al*., 2019).**

The presence of lead in water may be due to the application of lead and PVC pipes in addition to a spill of sewage from industries such as battery making, metal plating, electrical equipment, chemicals, steel, iron, and copper. Lead compounds are generally toxic pollutants which have bioaccumulation property in tissues of the human body. Human intestine absorbs lead, which may cause colics, skin pigmentation, and paralysis due to overexposure. Exposure to high levels of Pb (II) could damage the central nervous system and may lead to death. Chromium (VI), another toxic heavy metal pollutant, might lead to gastrointestinal disorders; liver, kidney, and lung cancer; cardiovascular shocks; and other health-related problem **(Orlovsky and Orlovsky, 2014).**

At acidic pH levels, heavy metals tend to form free ionic species, with more protons available to saturate metal binding sites. This means that at higher hydrogen ion concentrations, the adsorbent surface is further positively charged, thus reducing the attraction between an adsorbent and metal cation. Hence, heavy metals become more available, thereby increasing their toxicity to microorganisms and plants. At basic conditions, metal ions replace protons to form other species, such as hydroxo-metal complexes that are soluble as in the case of Cd, Ni, and Zn, while those of Cr and Fe are insoluble. A small change in the pH level can influence the solubility and bioavailability of heavy metals. Owing to large changes on the Earth's resources, environmental sustainability finds ways to reduce the harvesting of nonrenewable resources, as well as the effects of the activities associated with them on the Earth's biosphere.

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استعراض لدراسة تركيزات المعادن الثقيلة في المياه الجوفية في فيتنام

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تستند الدراسة إلى مبادئ بحثية تاريخية وموضوعية ووصفية تحليلية يتيح تطبيق هذه الأساليب في البحث اعتبار المعرفة العلمية كنظم متكامل يؤثر فيه كل نهج سابق بشكل غير مباشر أو مباشر على النهج التالي، كل هذا معًا جعل من الممكن تجميع سلسلة منهجية من الحسابات العلمية والنظرية حول هذه القضية، تتم مناقشة آراء المؤلفين بغض النظر عن الميول العرقية والثقافية والنظرية حول هذه القضية، تتم مناقشة آراء المؤلفين بغض النظر عن الميول العرقية والثقافية والميول السياسية، الأمر الذي يتطلب مقارنة شاملة للحقائق والظواهر في مجموعها، أي دراسة شاملة للمشكلة. بالإضافة إلى ذلك، يتم استخدام نهج منظم يأخذ في الإعتبار ميزات كائنات البحث نفسها والعوامل التي تحدد هذه الميزات في البحث، تسمح هذه الأساليب بتحديد ليس فقط الثغرات في الموضوع تحت الدراسة، ولكن أيضًا بعض الجوانب المعينة للمشكلة التي ربما لم تلفت انتباه العلماء لسبب أو لآخر، بشكل عام يتيح هذا الفرصة لمقارنة هذه الجوانب بموضوعية، وعلى أساسها تحديد احتمالات إجراء مزيد من البحث، تستعرض هذه الدراسة تركيزات المعادن الثقيلة لموارد المياه في فيتنام، تتجاوز تركيزات المعادن الثقيلة مثل As و Fe و Mn في المياه الجوفية من النهر الأحمر ودلتا نهر الكيونج إرشادات منظمة الصحة العالمية بشأن مياه الشرب، مما يعرض ملايين الفيتناميين للخطر الذي يعتمدون على المياه الجوفية في هذه المناطق كمصادر لمياه الشرب، يقترح الموقف حلاً لموردي مياه الشرب جنبًا إلى جنب مع تقنيات معالجة المياه الفعالة للمياه الجوفية أو مصادر مياه الشرب البديلة مثل المياه السطحية أو مياه الصنبور، فيتنام لديها تعداد سكاني متزايد واقتصاد متنام، وتخضع لتصنيع وتحضر سريع، من الاهمية بمكان أن يتم تطوير استراتيجيات جيدة لإدارة مياه الشرب الآمنة لكل من الإمداد العام والخاص، في المدن وكذلك في الريف، يعد تثقيف سكان المناطق الريفية لفهم آثار مياه الشرب الملوثة على صحتهم أمرًا ضروريًا، يجب أيضًا التفكير في برنامج مراقبة جودة المياه على المدى الطويل مع المزيد من الاختبارات المتكررة. في فيتنام، يتم الحصول على المياه الجوفية بشكل أساسي من الآبار الأنبوبية، التي تحتوي على تركيزات عالية من الملوثات مثل As و Fe و Mn و $NH4^+$ في المناطق التي أجريت فيها اختبارات المياه الجوفية، تراوحت مستويات الزرنيخ بين 0.1 – 3050 ميكروجرام/لتر، والتي تتجاوز بشكل كبير معيار 10 ميكروجرام/لتر الذي حددته منظمة الصحة العالمية، تتوزع مصادر التلوث على مساحة كبيرة من دلتا النهر الأحمر في الشمال إلى دلتا نهر ميكونج في الجنوب، مما يعرض ما يصل إلى عشرة ملايين شخص لخطر الآثار الصحية الضارة، ترتبط مستويات الزرنيخ والحديد في الرواسب ارتباطًا وثيقًا، مما يشير إلى أن وجود الزرنيخ ففي المياه الجوفية ناتج عن تقليل الزرنيخ المرتبط بأوكسي هيدروكسيدات الحديد من المهم رفع مستوى الوعي بهذه القضايا بين الجمهور الفيتنامي من خلال نشر المعلومات حول الآثار السلبية لمياه الشرب الملوثة، وكذلك تنفيذ مشاريع بحثية طويلة الاجل لتحديد مصادر التلوث الاخرى وتحسين تكنولوجيا معالجة المياه وقدرات إدارة المياه.

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