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Heavy metals-based water quality at Thiruvalluvar University mud Pond inSerkkadu Village, Vellore District, Tamil Nadu.

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Abstract

Water has emerged as a significant danger in contemporary society as a result of many contaminants. The accumulation of some heavy metals may be very harmful, and they can spread to many locations via diverse routes. The pollution of water sources has become a significant worldwide environmental issue, posing a danger to both aquatic ecosystems and human well-being. The fast expansion in the earth's population has led to a significant rise in development and industry, which are the primary causes of water pollution. Industrialization, climate change, and urbanization are causing an increase in heavy metal contamination in the aquatic environment. Pollution arises from several sources, including mining waste, landfill leachates, municipal and industrial wastewater, urban runoff, as well as natural occurrences such as volcanic eruptions, weathering, and rock abrasion. Heavy metal ions are highly poisonous, resistant to decomposition, and accumulate in increasing amounts as they move up the food chain in aquatic ecosystems. Eventually, they reach humans and cause damage to various organs in both aquatic organisms and humans, including the neurological system, liver, lungs, kidneys, stomach, skin, and reproductive systems. This harm can occur even at low levels of exposure. The tannery companies in Vellore District are discharging wastewater that is contaminating both the terrestrial and aquatic ecosystems within a radius of around 6 km. This is resulting in an increased concentration of heavy metals in the surrounding environment. The purpose of this research is to determine the levels of heavy metals such as cadmium, chromium,copper, lead and zinc to assess the water quality of Thiruvalluvar University Pond at Serkkadu, Vellore.The results of the present study indicated the heavy metals cadmium, chromium,copper, lead and zinc ranges were significantly beow to level of permissible limit of WHO standards therefore the water quality of the Thiruvalluvar University pond is potable for human.

Key words: Heavy metals, water quality,pond

Introduction

Ponds are stationary water pools originating from natural water flow or freshwater sources. They possess a rich variety of species and can support ecosystem functioning. Nevertheless, ponds are confronted with several challenges arising from human activities such as agricultural runoffs, pollution (Omuku *et al.,* 2012), excessive extraction of water for human use, land drainage, and inadequate or absent management (Chakravorty *et al.*, 2014). Various human activities, such as agriculture, industries, urban run-off, mining activities, and geochemical structures, contribute to the increase in pollution of heavy metals in aquatic environments. Human activities have introduced a substantial quantity of hazardous materials (HMs) into the environment (Bai *et al.*, 2024; Ustaoğlu *et al.*, 2021; Bai *et al.*, 2021; and Bashir, 2017). Heavy metals (HMs) released into rivers by mining activities, agriculture, and industries get lodged in sediments. These HMs then undergo translocation and bio-magnification, leading to the development of serious illnesses in fish and humans.

This phenomenon has been shown in studies by Le *et al.,* (2014), Shammout et al. (2023), Otchere (2019), Rogowska *et al.,* (2020), and Ali *et al.,* (2019). The proliferation of industry and agricultural sectors has significantly contributed to the pollution of water with metallic substances, exerting a detrimental influence on both the ecosystem and living beings (Stankovic *et al.,* 2014 and Islam *et al.,* 2022). According to Aliand and Khan in 2018, heavy metals (HMs) are characterized by having an elemental density (ED) of more than 5 g cm3 and an atomic number (Z) higher than 20. These metals, known for their non-biodegradable, cytotoxic, mutagenic, or carcinogenic qualities, present substantial concerns of environmental pollution (More *et al.,* 2003; Cuce *et al.,* 2022; Muhammad and Usman, 2022). Heavy metals pose significant risks to the aquatic environment due to their non-biodegradable nature. In addition, metals have a detrimental effect on organisms (MacFarlane and Burchett, 2000). Typically, the levels of heavy metals in aquatic environments are assessed by measuring their concentrations in water, sediment, and biota (Camusso *et al.,* 1995). Heavy metals (HMs) are well recognized for their toxicity to aquatic and terrestrial organisms, a major concern (Chaoua *et al.,* 2019). Nevertheless, HMs, or heavy metals, have long-lasting effects and threaten the well-being of organisms (Xue *et al.,* 2023; Azizullah *et al.,* 2011). Therefore, the current research aimed to assess the amounts of heavy metals, including cadmium, chromium, copper, lead, and zinc, in six distinct locations of the Thiruvalluvar University Ponds. The purpose was to determine the adequacy of the water quality for drinking, household use, and aquaculture practice.

Materials and method

Study sites

This study focuses on the Thiruvalluvar University reservoir, situated near the university library and computer complex, just across from the main building. The shape of a pond is similar to that of the single-celled organism paramecium. The pond is located at the foot of somewhat large hills, which are covered with thick vegetation consisting of tiny trees and plants and are made out of stones. In the rainy season, the water that flows down from the hills is collected and stored in the reservoir. Paramecium. The pond is surrounded by medium-sized hills that are heavily covered with tiny trees, grass, and stones. In the rainy season, the water that flows down from the hills is collected and stored in the reservoir. The pond's basement consists of rock, resulting in the pond's water being perennial.

Sample collection

This study carried out at Thiruvalluvar University, selected a total of six locations to collect water samples. The coordinates of these sample sites were documented on a global map as TVUPS-1, TVUPS-II, TVUPS-III, TVUPS-IV, and TVUPS-VI. The abbreviation TVUPS refers to the Thiruvalluvar University Pond Site, with the Roman numerals used to denote the specific site number. The choice of the sample place was carefully executed to include and faithfully depict the overall state of the pond water. The two sample locations were selected from the middle region of the pond to evaluate the water quality in its most profound section. Four additional sample sites were collected from the outside region of the pond, with one site chosen from each cardinal direction. Water samples were collected at each monitoring station over the whole year 2022, namely from January to December, using plastic bottles. The first month's sample collection was carried out on January 2nd, 2022, including all sample sites. Consequently, sample collection for the present study occurred on the second day of each following month. The table below presents the names, elevations, and longitudes of the sample sites.

Table-1. Shows the name, latitude and longitude of the sample sites

S.No	Name of the sample sites	Latitude-N	Longitude-E
1	TVUPS-I	13°01’43.46”N	79°12”32.43”E
2	TVUPS-II	13°01’41.93”N	79°12”33.08”E
3	TVUPS-III	13°01’40.71”N	79°12”32.74”E
4	TVUPS-IV	13°01’40.47”N	79°12”31.62”E
5	TVUPS-V	13°01’53.46”N	79°12”31.75”E
6	TVUPS-VI	13°01’42.16”N	79°12”32.56”E

Labeling of samples

The precise details, such as the collection location, date, and time, were documented on the sample collecting vial using a permanent glass marker that carries indelible ink.

Sample bottle preparation

Before obtaining the pond water sample, the plastic sample vial was cleaned with a phosphate-free detergent, followed by three rinses with cold tap water, a 10% hydrochloric acid solution, and deionized water.

Sample collection methods

The bottle cap was removed just before sampling. Precautionary measures were taken to avoid any contact with the inside of the bottle or its lid. The bottle was vertically oriented concerning the pond's surface. After the bottle was filled, it was securely closed with a cap.

Water sample processing for metal analyses

Water samples, each with a volume of 500 ml, were gathered from all six sampling sites and placed in an insulated container. Subsequently, they were conveyed to the laboratory located inside the Zoology Department. To evaluate the concentration of dissolved metal, each water sample in the laboratory was passed through a Whatman No. 41 filter paper with a pore size of 0.45 µm. Water samples, each measuring 500 ml, were obtained and treated with 2 ml of nitric acid to prevent the development of metal precipitates.

Acid digestion

The EPA strong digesting approach, as reported by Gregg (1989), was implemented.100 millilitres of each water sample were put into Pyrex beakers that contained 10 millilitres of concentrated nitric acid (HNO3). The samples were heated gradually and then reduced to the minimum volume achievable (about 20 ml) by evaporation on a heated surface. The beakers were let to cool, after which an additional 5ml of concentrated Nitric acid was introduced. The heating process was sustained by adding concentrated nitric acid as needed until the digestion was fully accomplished. The samples were evaporated once more until completely dry (without being subjected to high temperatures) and the beakers were then chilled. Next, 5ml of hydrochloric acid solution (in a 1:1 volume-to-volume ratio) was added. The solutions were heated and 5ml of a 5M NaOH solution was added, followed by filtration. The filtrates were transferred to 100ml volumetric flasks and then diluted with distilled water until the flasks were filled to the mark. These solutions were then used for elemental analysis. Heavy metal analysis (Pb, Cu, Cd, Zn, and Hg) was conducted using Atomic Absorption Spectroscopy.

Preparation of Pb Stock Solution with a Concentration of 1000mg/l

Measure the weight of about 1.0000 grams of lead (minimum purity 99.5%) to the closest 0.0002 grammes. Then, place the lead in a covered 250ml glass beaker and add 10ml of nitric acid (HNO3). Next, include 100 milliliters of water. Evaporate to remove nitrous fumes, let to cool, transfer to a 1000ml volumetric flask, and fill it to the mark with water.

Preparation of Lead Standard Solution with a Concentration of 10mg/L of Pb

Transfer precisely 10.00ml of a Pb stock solution into a volumetric flask with a capacity of 1000ml. Dispense 20 millilitres of nitric acid, then add water until the container is filled to the designated mark. Thoroughly blend the contents.

Preparation of Standard solution of lead Equivalent to a concentration of 0.4 milligrammes per litre of lead (Pb).

Transfer 20.00ml of a standard solution of Pb into a volumetric flask with a capacity of 500ml. Dispense 10 millilitres of nitric acid, then add water until the container is filled to the mark. Thoroughly blend the contents. Make this solution on the same day it will be used.

Preparation of Cadmium Stock Solution Corresponding to 1000mg/l of Cd

Weigh to the nearest + 0.0002gm, apx 1.0000gm Cd metal (minimum purity 99.5%) and dilute in a covered 250ml glass beaker with 40ml HNO3 . Then add 100ml of water.Boil to expel nitrous fumes, cool, transfer to 1000ml volumetric flask and fill to the mark with water.

Preparation of a standard solution of Cadmium with a concentration of 10mg/l

Transfer 10.00ml of Cd stock solution using a pipette into a 1000ml volumetric flask. Dispense 20 milliliters of nitric acid, then add water until the container reaches the designated mark. Thoroughly blend the contents.

Preparation of a standard solution containing cadmium at a concentration of 0.4mg/l

Transfer 20.00ml of a standard solution containing Cd into a volumetric flask with a capacity of 500ml. Dispense 10 millilitres of nitric acid, then add water until the container reaches the designated mark. Thoroughly blend the contents. Make this solution on the same day it will be used.

Preparation of a standard solution of Cadmium with a concentration of 0.02mg/l

Transfer 5.00ml of a standard solution containing Cd into a volumetric flask with a capacity of 100ml using a pipette. Inject 2 milliliters of nitric acid into the container, then add water until it reaches the designated mark. Thoroughly blend the contents. Make this solution on the same day it will be used.

Preparation of a Copper Stock Solution with a Concentration of 1000mg/l of Cu

Measure the approximate weight of 1.0000gm of Cu metal (with a minimum purity of 99.5%) to the closest + 0.0002gm. Then, place the metal in a covered 250ml glass beaker and add 10ml of HNO3. Next, include 100 millilitres of water. Evaporate to remove nitrous fumes, let to cool, transfer to a 1000ml volumetric flask, and fill it to the designated mark with water.

Preparation of a copper standard solution with a concentration of 10mg/l of Cu.

Transfer 10.00ml of the Cu stock solution into a 1000ml volumetric flask using a pipette. Dispense 20 millilitres of nitric acid, then add water until the container reaches the designated mark. Thoroughly blend the contents.

Preparation of a copper standard solution with a concentration of 0.4mg/l of Cu

Transfer 20.00ml of a copper standard solution into a volumetric flask with a capacity of 500ml. Dispense 10 millilitres of nitric acid and then add liquid until the container reaches the designated mark. Atomic absorption is used for the analysis of heavy metals. Perform spectroscopy on the samples collected around Visakhapatnam 131 by thoroughly mixing them with water. Make this solution on the same day it will be used.

Preparation of a Zinc Stock Solution with a Concentration of 1000mg/l of Zn

Measure the weight of about 1.0000gm of Zinc metal (with a minimum purity of 99.5%) to the closest + 0.0002gm. Then, place the Zinc metal in a covered 250ml glass beaker and add 40ml of HNO3. Next, include 100 millilitres of water. Evaporate to remove nitrous fumes, let to cool, transfer to a 1000ml volumetric flask, and fill it up to the designated mark with water.

Zinc standard solution prepared to have a concentration of 10mg/l of Zn.

Transfer 10.00ml of the Zn stock solution into a 1000ml volumetric flask using a pipette. Dispense 20 millilitres of nitric acid, then add water until the liquid reaches the designated mark. Thoroughly blend the mixture.

Preparation of a standard solution of Zn with a concentration of 0.4mg/l

Transfer 20.00ml of a standard solution containing Zn into a volumetric flask with a capacity of 500ml. Dispense 10 millilitres of nitric acid, then add water until the container reaches the designated mark. Thoroughly blend the contents.

Make this solution on the same day it will be used. Zinc, Standard Solution with a concentration of 0.02mg/l of Zn

Transfer 5.00ml of the Zn standard solution into a 500ml volumetric flask using a pipette. Dispense 10 millilitres of nitric acid, then add water until the liquid reaches the designated mark. Thoroughly blend the mixture. Make this solution on the same day it will be used.

Results and discussion

Cadmium is a metallic element with a silver-white colour, a little blue tint, and a shiny appearance. It has a melting point of 321°C and a boiling point of 765°C. According to Trotman-Dickenson's research in 1973, it is classified as the 67th most abundant element in the earth's crust. This element has a valence of 2, an atomic weight of 112.4, and an atomic number of 48. While its chloride and sulphate salts may dissolve easily, this substance cannot dissolve in water (Windholz, 1976). Cadmium (Cd) is categorised as a profoundly poisonous heavy metal (Håkanson 1980; Bojakowska and Sokołowska 1998). The high toxicity of this substance presents a significant danger to the growth and survival of plants and animals, as well as to human life and well-being (Bennet-Chambers et al. 1999). The addition of other hazardous metals, such as zinc, may worsen the toxicity of cadmium (Świderska-Bróż 1993). In this study, the Cadmium levels at all six sites of TVU ranged from a minimum of 0.00220.0014 to 0.00240.00013 and a maximum of 0.00870.00016 to 0.00940.00017. These levels are slightly below the water quality standard for drinking water set by the World Health Organisation (WHO, 1993), which is 0.003 mg/l. They are also significantly lower than the maximum allowable limit for Cadmium in drinking water, which is 0.01 mg/l according to the World Health Organisation (1971). However, the levels are slightly higher than the recommended limit of 0.02 mg/l for fish production in African inland water bodies, as stated by Lioyd (1992). Cadmium is readily absorbed and tends to accumulate in tissues. The primary dietary sources of cadmium are fish and grain products (Olmedo *et al.,* 2013). Prolonged exposure to Cd may result in renal, hepatic, testicular, and prostatic damage. Excessive exposure to Cd may also lead to anemia, hypertension, circulatory issues, bone decalcification, and muscular atrophy (Kabata-Pendias and Pendias, 1993). Due to its poisonous nature, Cadmium (Cd) is deemed nonessential for the optimal functioning of living organisms.

Chromium (Cr) is extensively used, along with lead, cadmium, and copper, in the manufacturing of colour pigments for textile dyes. As a result, it is a prevalent pollutant found in the effluents of textile factories (Ugoji and Aboaba, 2004; Manzoor *et al.*, 2006; and Deepali and Gangwar, 2010). Chromium has a vast distribution across the Earth's crust. It may occur in valences ranging from +2 to +6. Chromium (Cr) is well recognized as the second most prevalent inorganic pollutant found in groundwater at hazardous waste sites (Blowes, 2002). Chromium (Cr) (III) salts are used as tanning chemicals in around 90% of tanneries globally (Mwinyihija, 2008, Alibardi, 2016). Chrome tanning involves the use of 276 chemicals and 14 heavy metals, which significantly contribute to water contamination (Ramasamy and Naidu, 1998). Hexavalent chromium sometimes referred to as chromium VI or Cr VI, is a significant heavy metal contaminant in aquatic environments owing to its ability to dissolve, move, and persist in water for extended periods of time. Chromium is very cancer-causing; as a result, it is recommended to consume as little as possible (WHO 2011). According to Engwa *et al.*, (2018), if people are exposed to very high amounts of chromium (VI) compounds, it may have serious effects on the cardiovascular, respiratory, hematological, gastrointestinal, renal, hepatic, and neurological systems, and may even lead to death. In this investigation, the minimum chromium level ranged from 0.340.020 to 0.78 0.046, while the highest level ranged from 1.75013 to 1.910.13. These levels were much higher than the World Health Organization's limit of 0.05 mg/L. Therefore, the water from the TVUPS is not suited for drinking or other household uses.

Copper is a naturally occurring reddish metal found in rock, soil, water, sediment, and air. Its unique chemical and physical characteristics have made it exceptional. It occupies the 29th position in the Periodic Table of Elements. Copper has a ground-state electronic structure and is found in the environment in three primary valence states: copper metal (Cu^{o}), Cu(I), and Cu(II). It is considered one of the most economically significant metals. Copper (II) is a prevalent heavy metal in the environment. Copper (II) is a vital element for several animals and plants and may naturally build up in the food chain (Briffa *et al.*, 2020). While copper is necessary for human metabolism, consuming overly high amounts may cause significant irritation and corrosion of the mucosal lining, widespread damage to capillaries, as well as harm to the liver, kidneys, and central nervous system, leading to subsequent melancholy. Human activities may result in the release of copper into the environment, particularly onto land. Mining activities, in addition to incineration, are the primary contributors to the emission of copper. Agricultural fertilizers and pesticides, mining activities, and chemical, pharmaceutical, and paper manufacturing sectors are the main sources of Cu(II) in the environment (Wołowiec *et al.*, 2019). The release of copper into water is caused by the erosion of soil, industrial emissions, sewage treatment facilities, and the use of antifouling coatings (IPCS 1998).In this study, all six TVUP sites exhibited a maximum copper level of 0.00920.0002mg/L in May and a minimum level of 0.00190.0015mg/L in December. These levels are below the suggested limit of 1mg/L for drinking water according to the World Health Organisation (WHO, 1993), and the favourable limit of 5mg/L for aquatic life according to Vezeau (1989). Therefore, the copper content in all the sample stations is within the allowed amount set by WHO and ISI.

Environmental contaminants, such as lead, are common. Toxic contaminants include lead and its compounds. Ecotoxicologically, lead (II) salts and organic lead compounds are the most dangerous substances. Water hazard class 2 includes dangerous lead salts. Aquatic animals are very poisonous to organic lead compounds, such as tetraethyl- or tetramethyl-lead. Unlike DDT, PCBs, methyl mercury, and organic forms of lead, inorganic, or metallic, forms of lead do not biomagnify up food chains. Elevated levels of lead in drinking water may harm skin, create issues with the circulatory system, and raise the risk of cancer. Lead is an established neurotoxin. According to Goldstein (1990), lead may pass across the blood-brain barrier. There is currently no known safe blood lead threshold, which makes lead exposure especially dangerous for children. Lead exposure is linked to several negative health effects (WHO,2006; Davis *et al.,* 2018). It is generally known that exposure to lead may have serious impacts on cognitive health, as well as other symptoms including weakness, high blood pressure, memory loss, stomach discomfort, and kidney damage (USEPA, 2020). Lead exposure in kids may have a lot of negative health impacts, such as delayed development, cognitive decline, encephalopathy, kidney damage, and issues with their offspring's development (ATS and DRLT, 2020). The World Health Organization's and the US Environmental Protection Agency's maximum allowable concentrations of lead in drinking water are 0.015 mg/l and 0.0003 mg/L, respectively. The present investigation's minimum and maximum lead content, which were 0.0003 mg/L and 0.0048 mg/L, were significantly lower than these levels (WHO,2006).

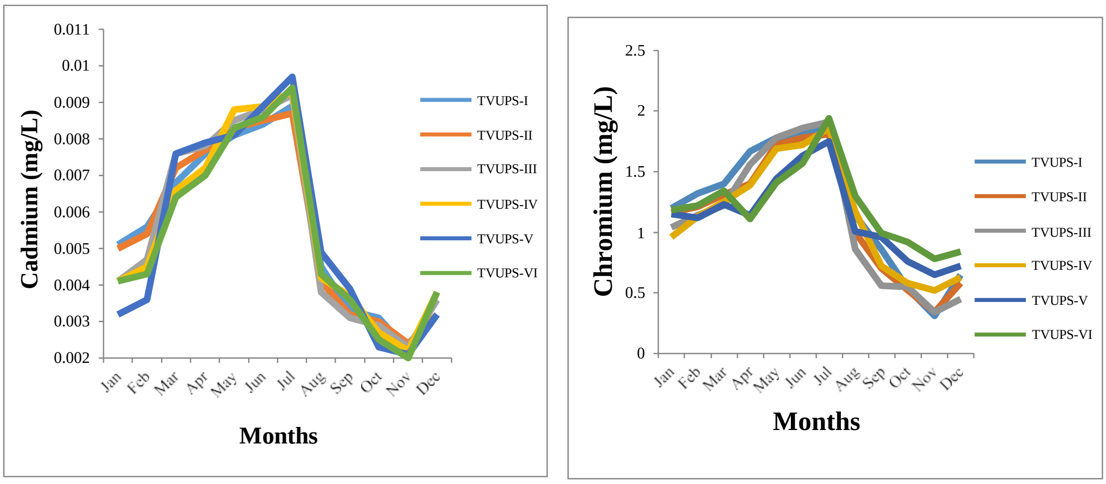
Zinc has an atomic number of 30 and an atomic weight of 65.38 (Weast, 1977). Zinc's chemistry is comparable to that of cadmium, which is right below it on the periodic table (Cotton and Wilkinson, 1972). Zinc always has a +2 valence in aqueous solution and possesses amphoteric properties, dissolving in acids to create hydrated Zn(II) cations and in strong nases to generate zincate anions [most likely Zn(OH)42]. Zinc compounds containing common surface water ligands are soluble in neutral and acidic solutions, making zinc one of the most mobile heavy metals. Zinc is a frequent trace ingredient of natural fluids and an essential trace element in the metabolism of most organisms. To operate correctly, an organism's uptake of zinc from the environment, whether by intake or absorption, must surpass a certain minimum rate.

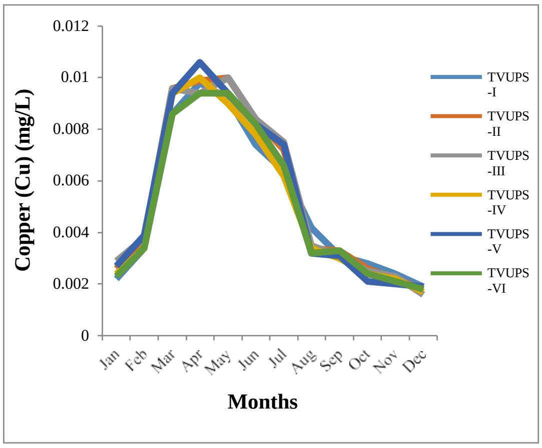
Zn is an essential cofactor in a variety of enzyme systems that conduct catalytic, structural, and regulatory roles, including polysome conformation and nucleic acid synthesis (Buentello *et al.*, 2010; NRC, 2011). Zn, in particular, is a critical component of the superoxide dismutase (SOD) enzyme, which regulates the immune response by interacting with minerals such as copper (Cu), magnesium (Mg), selenium (Se), and several metalloenzymes (Lothar, 2000; Bonaventura et al., 2015; Musharraf and Khan, 2019). The readings obtained fell below the WHO's (2011) permitted Zinc threshold of 5.0 mg/l in drinking water. The levels of zinc in surface water and groundwater normally do not exceed 0.01 and 0.05 mg/l. (WHO, 2003). Heavy elements like cadmium, chromium, copper, lead, and zinc found in Thiruvalluvar University's surface water were all within WHO-permitted levels from January to December 2022. These results show that heavy metal pollution of pond water has not affected the aquatic biota, indicating that the water quality is satisfactory for heavy metal levels.

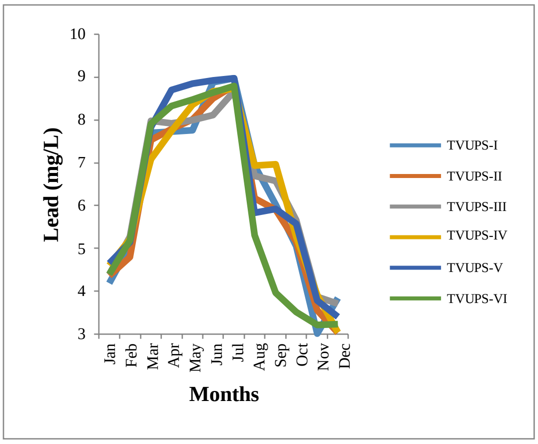
Conclusion

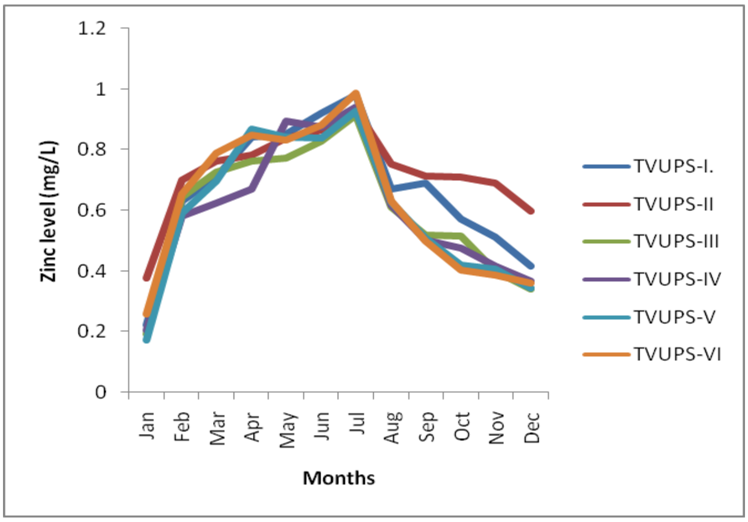
The degradation of water quality due to heavy metals such as cadmium, chromium, copper, lead and zinc in the tannery industrial area of Vellore District is a serious issue that demands immediate attention. Hence the present study has been carried out to asses the water quality of Thiruvalluvar University based on the heavy metals concentration in the surface water. The obtained results indicated that all the metals in all the sample sites of the pond were significantly lower than the WHO permissible limit.So the water quality is good for drinking purpose.

Figure-1-5. shows the cadmium, chromium, copper, lead and zinc concentrations in the surface water of all six sites TVUP from January to December-2022.









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