Intensity of Pollution and Heavy Metals Toxicity on Surface Water Bodies of Coimbatore, Tamilnadu, India - A Case Study

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Abstract  Diminishing in the quality of lake water is one of the emerging serious threats for the last few decades. The lakes occupied in the vicinity of cities and towns receive more anthropogenic activities under which the six stations, are Perur (L1), Selvachinthamani (L2), Ukkadam (L3), Kurichi (L4), Valankulam (L5) and Singanallur (L6) lakes of Coimbatore, Tamil Nadu, India was chosen for the study. The sampling stations are selected based on their location and susceptibility to anthropogenic pressures. The main objective of this work is to investigate and monitor the changes that occurred in the Physico-chemical and Heavy metal of surface water in selected lakes under pre-monsoon period are followed based on the procedure proposed by APHA and NEERI. In Physico-chemical and heavy metal analysis, the Singanallur lake showed higher concentration for most of the parameter and the Perur as the minimum. The concentration observed in the other lakes ranges moderate. All the sample concentration of the lakes are compared with the standards of WHO, BIS and EPA. Deterioration in the quality of water was observed that may be due to the dumping of domestic sewage and pressure extended due to the increased Urbanization.

Keywords: Physico-Chemical, heavy-metals, lakes, water quality, ICP-MS

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1. Introduction

Water is the most momentous resource that all living organisms in the earth are dependent on it. The surface of the universe is covered by water about 70% of water. A human body contains about two-third of water which helps to maintain the metabolism of the body. Comparing with other resources, water is considered as the most unique and dynamic one. In the biosphere, the water is available everywhere in the three forms, solid (ice and glacier), liquid (ocean, river, lakes) and gas (mist) [1]. In most of the cases, people use surface water bodies like lake, river and ocean as a place for disposal of untreated domestic sewage and industrial effluents. This activity results in the degradation of the water and made it to unfit for primary and secondary uses. Continuous release of sewage into these surface water bodies also affects bore well, river and lakes makes water non-optimal for consumption before treatment and leads to a severe scarcity of drinking water all over the world [2].

Lakes and tanks are considered to be the significant watershed, multi-usage components by offering drinking water, irrigation, agriculture output, fishing sector, etc. They solely associated with water quality and improve the groundwater table. Quality of the water close to aquifers due to the prevalence of direct association between surface and groundwater. The water quality is influenced by various natural sources like the degree of weathering of rocks, seasonal variation, topography of ground and discrepancy is monsoonal rainfall [3]. The other reasons for the pollution of water are urbanization, industrialization and the proliferation of chemicals [4]. Increase in urbanization due to their location occupied closer to the hot urbanized sector of the cities (Palma, 2010) and the expanded economic alleviation strategies an important problem for the pollution in the water resulting in 13% of the world population unable to access drinking water [5]. This may lead to half of the world population suffer from water scarcity by 2030 [6].

The sudden increase in population is the main cause of industrial development and the over-exploitation of natural resources causes the release of the organic and inorganic compounds into the aquatic streams which causes adverse effects to the animals and plant which will not provide a balanced ecosystem [7]. The productivity of the lake is mainly influenced by the physical and chemical properties of water and sediment but the discharge effluents to the lake will greatly affect the water quality. Several studies have been extensively carried out on the anthropogenic pollutant’s effects on the lake ecosystems [8]. Many new water-borne diseases are identified to the people residing nearby to the contaminated lakes. The
people are exposed to the lake through consumption of water and fish from the lake, washing of clothes, bathing etc. The periodical monitoring is more important for the successful fish production process [9]. All these lakes lie predominantly in the industrial zone with heavy population and agriculture activities with poor drainage and sewerage system. Industries like spinning mills, four mills, and small scale industries are the source of the pollution in this lake [10].

Industrial discharge is the main factor that makes a broad path for the intercourse of heavy metals into water will cause a serious impact on hydro chemistry and biological reliability on water bodies. Residues of the heavy metal in contaminated habitat will be absorbed by water plants and animals will enter into the human food chain and cause severe health impacts [11].

Abdominal pain, headache, irritability, blood pressure, kidney damage, nerve damages, skeletal damage, cancer and upsets intellectual functions are some of the serious toxic effects caused by heavy metals to humans [12,13].

2. Materials and Methods

2.1. Study Area

Coimbatore city is one of the versatile and industrial based and it is located between 10° 55’ and 11o 10’N and 77°10’ and 76° 10’E. The average annual temperature is found to be 26.3°C, and rainfall was recorded as 618 mm annually. Major popular rivers flowing through the city are Noyyal, Aliyar, Amaravathi, Bhavani and Kousika which are fed with 28 Lakes occupying around the city. Perur, Selvachinthamani, Ukkadam, Kurichi, Valankulam and Singanallur lakes that lie within the city area prone to higher pollution were selected for the study (Figure 1 and Table 1).

![Figure 1. Location of the six lakes used for the study in Coimbatore, Tamil Nadu, India](image-url)

| Lake       | Latitude and Longitude | Ayacut (acres) | Capacity (Mc.ft) | Water source                                                                 | Inlets, Outlets          |
|------------|------------------------|----------------|------------------|------------------------------------------------------------------------------|--------------------------|
| Perur      | 10°59’13.8”N 76°53’45.1”E | 866            | 51.94            | Kuniyamuthur anicut channel, GangaNarayanaSamudram                            | 2 weirs, 6 sluices       |
| Selvachinthamani | 10°59’30.2”N 76°56’49.5”E | 72             | 3.02             | Chittirai chavadi anicut, Kumaraswamy lake.                                   | 3 vents, 1 sewage inlet |
| Ukkadam    | 10°58’56.4”N 76°5721.5”E | 1425           | 69.95            | Selvachinthamani lake, Noyyal river                                            | 1 weir, 4 sluice         |
| Kurichi    | 10°57’58.7”N 76°57’50.1”E | 452            | 60               | Municipal sewage, Noyyal river                                                 | 1 weir, 5 sluice         |
| Valankulam | 10°59’36.9”N 76°58’49.0”E | 870            | 27.88            | Ukkadam Big tank                                                               | 1 weir, 5 sluices        |
| Singanallur | 10°59’28.1”N 77°01’21.3”E | 845            | 52.27            | Singanallur anicut channel                                                    | 1 weir, 3 sluices        |
2.2. Sample Collection

The water samples were collected from sampling stations, such as Perur, Selvachinthamani, Ukkadam, Kurichi, Valankulam and Singanallur lakes during the Pre-monsoon (March 2019) period by morning between 8 and 11 AM systematically following the appropriate methodology. Samples were collected at a depth of 5 ft. using Niskin water sampler, from the surface level by initial DO baseline. Collected water was sample directly transferred to previously acid-washed amber polyethylene bottles. Oxygen was fixed in the field itself by introducing 1ml of MnSO₄ and Alkali Oxide iodide solution.

2.3. Analytical Methods

Physicochemical characteristics and heavy metal concentration were tested for all the collected samples in the laboratory as given in Table 2. For the water sample analysis, the APHA 2005 [14] and NEERI [15] standard methods are followed. Heavy metals such as Silver (Ag), Aluminium (Al), Arsenic (As), Barium (Ba), Beryllium (Be), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Lithium (Li), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Lead (Pb), Antimony (Sb), Selenium (Se), Tin (Sn), Strontium (Sr), Titanium (Ti), Thallium (Tl), Vanadium (V), Zinc (Zn) were also analyzed using ICP-MS.

2.4. Statistical Analysis

An important component of the research is data collection and analysis. The collected data were subjected to one-way analysis of variance (ANOVA), and the significance of the difference between means was determined by Duncan’s multiple range test (P < 0.05) using IBM SPSS Statistics 26. Values expressed are means of triplicate determinations ± standard deviation.

3. Results and Discussion

The quality of the water collected from Perur, Selvachinthamani, Ukkadam, Kurichi, Valankulam and Singanallur lakes were measured and the results are presented in Table 4. The standard values of physicochemical and heavy metals by WHO, EPA, BIS are given in Table 3.

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**Table 2. Methods and Instrument used for the investigation of water samples**

| Analysis                        | Methodology                        | Instrument          |
|---------------------------------|------------------------------------|---------------------|
| Temperature, pH, Conductivity, Salinity, TDS | Electronic Method                  | Eutech - PCSTester-35 |
| Alkalinity                      | Sulphuric acid titration method    | Microlit E-Burette (50ml) |
| BOD                             | 5 day Incubation at 20°C           | Microlit E-Burette (50ml) |
| DO                              | Winkler Method                     | Microlit E-Burette (50ml) |
| COD                             | Closed reflux method               | Digital COD digester |
| Hardness                        | EDTA titration method              | Microlit E-Burette (50ml) |
| Fluoride                        | SPADNS method                      | Spectrophotometer (Shimadzu UV-1800) |
| Nitrate, Nitrate-Nitrogen       | Electronic method                  | Horiba (LAQUAtwin-NO3-11) |
| Phosphate, Orthophosphate       | Stannous Chloride method           | Spectrophotometer (Shimadzu UV-1800) |
| Sulphate, Sulphur               | Barium Chloride (Turbid metric) method | Thermo (Turbidity meter TN-100) |
| TS, TSS                         | Gravimetric method                 | Genuine hot air over 250°C |
| Turbidity                       | Electronic method                  | Shimadzu Electronic Balance (1mg - 220g) |
| Chloride                        | Argentometric Method               | Labtronics (LT-671) |
| Na, Ca, K, Li                   | Digital Flame Photometer           | ICP-MS, NexION 300x, Perkin Elmer, USA |
| Heavy Metals                    | Electronic method                  | Secchi disk |
| Transparency                     | Manual method                      | General Oceanics-1010 (1.7 Litres) |
| Water sampling                  | Niskin water sampler               | Garmin - (GPS 64s) |
| Location                        | Digital method                     |                     |

**Table 3. The maximum permissible limit for water Physicochemical [16-22]**

| Parameter       | Maximum Permissible Limit | Organization | Parameter       | Maximum Permissible Limit | Organization |
|-----------------|---------------------------|--------------|-----------------|---------------------------|--------------|
| Temperature     | 30°C                      | WHO          | Phosphate       | 5 mg/L                    | EPA          |
| pH              | 6.5 - 8.5                 | WHO          | Orthophosphate  | N/A                       | N/A          |
| ORP             | N/A                       | WHO          | Sulphate        | 400 mg/L                  | BIS          |
| TDS             | 2000 mg/L                 | BIS          | Sulphur         | N/A                       | N/A          |
| Conductivity    | 4.0 mS/cm                 | EPA          | TS              | N/A                       | N/A          |
| Alkalinity      | 600 mg/L                  | EPA          | TSS             | 200                       | WHO          |
| BOD             | 5 mg/L                    | WHO          | Transparency    | N/A                       | N/A          |
| COD             | 250 mg/L                  | CPCB         | Turbidity       | 5NTU                      | WHO          |
| DO              | 6 mg/L                    | WHO          | Chloride        | 250 mg/L                  | WHO          |
| Total Hardness  | 500 mg/L                  | WHO          | Salinity        | 3500 mg/L                 | WHO          |
| Ca hardness     | 200 mg/L                  | WHO          | Sodium          | 60 mg/L                   | EPA          |
| Mg hardness     | 100 mg/L                  | WHO          | Calcium         | 200 mg/L                  | BIS          |
| Fluoride        | 1.5 mg/L                  | BIS          | Potassium       | 20 mg/L                   | WHO          |
| Nitrate         | 75 mg/L                   | BIS          | Magnesium       | 100 mg/L                  | BIS          |
| Nitrate-Nitrogen| N/A                      |              |                 |                           |              |

WHO- World Health Organization, EPA- Environmental Protection Agency, BIS- Bureau of Indian Standards
3.1 Temperature, pH, Electrical Conductivity, ORP and Turbidity

Figure 2 shows the variation among the studied lakes. The water collected from the lake showed the temperature between 27.7°C minimum and 31.7°C maximum. However, 30°C is optimum as per the WHO standard. The observed value was found to be high in Perur Lake whereas others exhibited were on the line of verge. The temperature of the water showed a significant role in limiting the Oxygen content. Studies were reported that water temperature with season, elevation and water received affluent from Industrial activities and groundwater inputs.

pH study used to determine whether water is acidic or alkaline. The value decides the suitability of water for irrigation, drinking and aquafarm growth. The level of pH of six lakes was recorded as 7.17 maximum and 7.03 minimum. It is interesting to state that the obtained values were less than as recorded in previous studies [23] and indicated unpolluted. The electrical conductivity of water is found to be minimum 0.2 ms/cm from Perur and maximum of 2.29 mS/cm from SInganallur. In this test, Singanallur lake has shown maximum conductivity may be attributable to the salt dissolve ability that enables them to hold an electrical conductivity. The concentration of the lake also under the limit of FAO and increase conductivity leads to quality degradation and deterioration of the aquatic ecosystem [23].

The ORP of the lakes ranged from minimum to maximum of -1.71 mV to -9.71 mV respectively. The Oxidation-reduction potential (ORP) is reducing or oxidizing capacity of the water. The level of the oxygen will be higher than 1 mg/L if the redox potential ranges from 300-500 mV. In the isolated or less exposed area, such as in the deep-water of stratified lakes or the sediment of eutrophic lakes, the redox potential will be lesser than 100 mV to -300 mV. Microbial redox process will reduce the redox potential to -300 mV or lower [24]. Turbidity is a physical character that indicates the transparency of water. Tested samples showed that a maximum of 50.85 NTU in Ukkadam, 14.74 NTU in Valankulam Lake as minimum was detected. As per WHO and FAO standards permissible limit of turbidity ranges between 5 NTU and 25 NTU is allowed for drinking and irrigation usages. The turbidity concentration of all lakes is comparatively higher about two to three times of the previous report by Jeyaraj 2016 [23].

3.2. Salinity, Solids (TDS), Alkalinity

Figure 3 shows the deviation of solids among the selected lakes. TDS represented the presence of Na, K, Ca, Mg, Mn, CO$_3^-$, Bicarbonates Cl, PO$_4$ organic matter and other sized particles [26]. The TDS content in selected
lake samples was found to be 141.11 mg/L minimum and 1624.07 mg/L maximum in Perur and Singanallur lakes respectively. An increased level of TDS was observed than the earlier report of Jeyaraj et al., 2016 [23] studies. The level is found to the permissible limit as per the standard of BIS. Increased level of TDS indicated may be due to extraneous sources to this specific lake [27]. Similarly, total suspended solids (TSS) observed was within the range of 95.10 mg/L in Perur lake, 1466.11 mg/L in Singanallur. The permissible limit to the maximum has been based on 200 mg/L according to WHO. Total solids (TS) denote matter suspended or dissolved in water and close association with specific conductance and turbidity. The concentration level of TS was recorded and ranged from a minimum value of 236.22 mg/L in Perur Lake and maximum of 3090.22 mg/L in Singanallur Lake.

### 3.3. Hardness

Figure 4 shows the inequality of hardness among the selected lakes. Hardness is represented by the presence of total polyvalent cations in the water. Commonly divalent cations are known to be calcium and magnesium. The tested samples showed the hardness maximum as 514.44 mg/L (Singanallur) and the minimum value was 48.88 mg/L (Selvachinthamani) were recorded and is slightly higher than the standard limits of WHO. Calcium hardness was found to be 3.87 mg/L minimum and as 62.78 mg/L maximum value. Mg” hardness was also recorded as min 3.95 mg/L and 123.5 mg/L as maximum whereas control WHO standard is 100 mg/L. When the hardness of water is less than 75 mg/L is considered to be as soft water and if the range is 150 mg/L or above are unsuitable for drinking purposes [28].

Alkalinity is a chemical property that accelerates and potential to neutralize the acidic nature of the water body. The tested sample concentration of alkalinity was observed as 220.55 mg/L minimum to 1112.22 mg/L maximum. Alkalinity would be increased if the pH level is increased above 7.0. The concentration of the Perur, Kurichi and Ukkadam lakes are higher than the previously recorded data by Chandra 2010 [29].

![Figure 2. The level of Temperature, pH, ORP, Conductivity and Turbidity of selected lakes](image2)

![Figure 3. The concentration of TDS, TS, TSS, Salinity, Alkalinity of selected lakes](image3)
3.4. Nitrate, Nitrate-Nitrogen, Phosphate

Figure 5 shows the changes between the selected lakes. Nitrate concentration was recorded ranging from 13.55 mg/L to 44.90 mg/L. BIS permissible limit is 75 mg/L. The observed value of nitrate may be attributed to the runoff water from adjacent agricultural land in which they used fertilizers in excess. The nitrate will enter into from atmosphere, reaming’s of plant, waste of animal. If the water concentration is more than 100 mg/L then the water will taste bitter. The normal concentration of the drinking water will be less than 10 mg/L. The nitrate concentration is ranged from minimum 2.98 mg/L to 9.89 mg/L maximum. The Singanallur lake showed more concentration and less in Perur. The concentration was higher is due to the excess discharge of domestic and sewage effluent to the lake. The water of all the six lakes ranges under the standard limit and indicate safe.

The phosphate content of tested samples is found to be ranging from 3.49 mg/L to 16.51 mg/L and absent in Perur Lake. Nitrate and phosphate are considered to be the nutrient source of an aquatic ecosystem. In earlier studies, high concentration was observed. However, its abundance caused negative effects in drinking water such as gastric cancer. The higher values are indicated may be due to the influx of sewage, contaminant disposals of phosphate enter into the lake through domestic sewages and enhanced the level of PO₄ and NO₃ in lakes leads to the accumulation of plankton productivity.

3.5. Dissolved oxygen, BOD, COD, Chloride

Dissolved oxygen is a remarkable criterion in aquatic life forms. The abundance of dissolved oxygen would lead to suppressing the growth of photosynthetic microorganisms such as phytoplankton and it caused changes in the coloration of water colorless to green. Therefore, dissolved oxygen may be considered as a bio indicator of the aquatic ecosystem. In the Figure 6, dissolved O₂ content shown to be the range between 3.59 mg/L to 29.83 mg/L as the maximum was recorded. Consequently, Biological oxygen demand of the chosen water samples was found to be the range between 2.91 mg/L to 18.5 mg/L. BOD represents the utilization of oxygen present in the water for the degree of destruction of organic matter and the permissible limit is commanded by WHO is 6 mg/L. Similarly, chemical oxygen demand (COD) of the sample water was observed as 144.99 mg/L as a minimum in Selvachinthamani to 643.66 mg/L as a maximum at Perur lake and its limitation as per Central Pollution Control and WHO based is 250 mg/L. COD is a bio indicator that was measured by determining the total quality of O₂ required to oxidize the entire organic matter into carbon dioxide and water. The higher value than the permissible limits of the BOD and COD concentration is an indication of oxygen demand and this is due to the addition of sewage to the lake waters without pre-treatment.

Chloride is the most remarkable component to access its presence in the water and its lower limit prevalent indicates the suitable for drinking and agricultural purposes. If the concentration of chlorine is increased, the level of pollution has also been elevated. The test results are ranged from 13.23 mg/L to a maximum at Perur lake and 365.60 mg/L as a minimum in Selvachinthamani respectively and the allowed limit of Cl⁻ as per WHO standard protocol is 250 ml/L. The concentration of the chlorine above 250 mg/L will create an unacceptable taste. Till date, no evidence or severe effect have been observed on human beings due to the prolonged consumption of high chlorine content in water.

3.6. Orthophosphate, Sodium, Potassium, Calcium

Figure 7 shows the divergent between the selected lakes. Orthophosphate is a contaminant of water that found the least quantity in unpolluted water. It has been generated by mankind through a discharge of partially treated effluent, dumping of untreated sewage, runoff from fertilized used agricultural land. In nature, organic phosphate tends to bind with plant tissue, waste solids and other organic products. After a complete decomposition of organic matter, orthophosphate is an end product. Phosphorous is a key growth-limiting nutrient, and nontoxic to mankind within the limit. Orthophosphate also inhibits dissolution of lead carbonates or other lead compounds by adsorbing to and...
passivating mineral surfaces [35]. In the present investigation, the presence of orthophosphate range between 10.7 mg/L to 50.62 mg/L as maximum and unavailable at Perur lake.

Figure 5. The concentration of Nitrate, Nitrate-Nitrogen, Phosphate of selected lakes

Figure 6. The level of BOD, COD, DO, and Chloride of selected lakes

Figure 7. The level of Orthophosphate, Sodium, Calcium, Potassium of selected lakes
Sodium is an element with highly soluble in water. Due to its solubility, the abundance of sodium-containing materials deposits was found in the sample. Under EPA guidelines permissible limit of Na in drinking water is 60mg/L. The tested sample exhibited the Na⁺ level range from 9.17 mg/L to 232.88 mg/L. The concentration of the Singanallur sample is three times higher than the standard limit. The exceeded limits of the sodium in drinking water and surface water will above the permissible limit cause heart problems in drinking water and salinity issues in the surface water. Potassium is a limiting factor for the growth of terrestrial vegetation. It is obvious in the observation that increased potassium level 7.06 mg/L to 35.41 mg/L, the range may be due to the surface runoff from agricultural land located in the vicinity of the lake with WHO limit is 20 mg/L as standard. The concentration of the water will increase due to the presence of silicate which is originated from igneous and metamorphic rocks [25].

Calcium is meant for bone growth of aquatic animals and one of the important factors to the hardness. They may exhibit negative effects on other compounds. Calcium directly influences human health. The presence of calcium is due to the dissolution of gypsum and calcaeous rock. The discharge of various effluent into the water leads to a hike of calcium concentration [11]. Findings of the given samples showed that abundant calcium is found to be the range from 23.39 mg/L to 55.43 mg/L at maximum. The acceptable limit of calcium in drinking water is 200mg/L as per BIS reports.

3.7. Magnesium, Fluoride, Sulphate, Sulphur

Figure 8 shows the divergent between the selected lakes. Normally the magnesium salts are found naturally in surface water and second highest in abundance after the sodium salt. The maximum abundance of magnesium in the water body is due to the washout of bedrock by water [36]. In this study, the concentration ranged from 4.22 mg/L minimum to 53.22 mg/L maximum in Perur and Singanallur lake, where the limit is 100 mg/L (BIS).

The fluoride concentration ranged from 11.87 mg/L minimum to 36.32 mg/L maximum. The maximum permissible limit for drinking water is 1.5 mg/L. If the concentration of the fluoride in drinking water exceed above 1.5 mg/L will leads to the cause of dental fluorosis. The concentration observed in this study which approximately twenty times greater standard and the water is unsuitable for consumption [37]. Sulfate (SO₄) is commonly available in all water bodies which is one of the major dissolved components of rain. Maximum concentrations of sulfate in the drinking water can cause a laxative effect when mixes with Ca and Mg ions. The Sulphur content of the sample ranged from 6.66 to 117.29 mg/L. The Perur samples showed minimum and Singanallur as maximum. Increasing of the Sulphur content in the water leads to acidification of water and it will deteriorate the aquatic life. The prolonged exposure to the maximum level of Sulphate and Sulphur will cause human health effects like gastrointestinal tract problem, diarrhea, nausea, bowel inflammation disease [38].

3.8. Heavy Metals

The water collected from the selected from various lakes of Coimbatore showed divergent concentration for the heavy metal analysis. Pre-monsoon is a season where the evaporation is comparatively more with other seasons. The quality of the water collected from Perur, Selvachinthamani, Ukkadam, Kurichi, Valankulam and Singanallur lakes were measured and the results are presented in Table 6. The standard values of physicochemical and heavy metals by WHO, EPA, BIS are given in Table 5.
The Cadmium of the investigation ranged from 0.04 to 0.4 µg/L and concentration is well under control and behind the limitations of 3 µg/L (WHO). Cadmium is a toxic heavy metal which is naturally available and also created by human activities. The accumulation of cadmium in the human body will cause serious issues of kidney, nervous system (CNS), biochemical damage of kidney, nervous system (CNS), biochemical effects and reproductive effects [7].

The Antimony of the samples ranged from 0.07 to 0.83 µg/L, the permissible limit is 0.6 µg/L (WHO). The

**Table 6. Heavy metal concentration of the selected lakes**

| Parameter | Maximum Permissible Limit | Organization | Parameter | Maximum Permissible Limit | Organization |
|-----------|---------------------------|--------------|-----------|---------------------------|--------------|
| Ag        | 70 µg/L                   | EPA          | Mo        | 10 µg/L                   | WHO          |
| Al        | 1500 µg/L                 | EPA          | Ni        | 20 µg/L                   | WHO          |
| As        | 50 µg/L                   | EPA          | Pb        | 10 µg/L                   | WHO          |
| Ba        | 1000 µg/L                 | EPA          | Sb        | 0.6 µg/L                  | EPA          |
| Be        | 100 µg/L                  | EPA          | Se        | 10 µg/L                   | WHO          |
| Cd        | 3 µg/L                    | WHO          | Sn        | 2 µg/L                    | WHO          |
| Co        | 50 µg/L                   | WHO          | Sr        | 4000 µg/L                 | EPA          |
| Cr        | 50 µg/L                   | WHO          | Ti        | N/A                      | N/A          |
| Cu        | 2000 µg/L                 | WHO          | Th        | 2 µg/L                    | EPA          |
| Fe        | 300 µg/L                  | WHO          | V         | N/A                      | N/A          |
| Li        | 700 µg/L                  | EPA          | Zn        | 5000 µg/L                 | WHO          |
| Mn        | 10 µg/L                   | WHO          |           |                           |              |

WHO- World Health Organization, EPA- Environmental Protection Agency, BIS- Bureau of Indian Standards.

**Table 5. The maximum permissible limit for water Heavy metal [17,22,39,40,41,42]**

| Parameter | Maximum Permissible Limit | Organization | Parameter | Maximum Permissible Limit | Organization |
|-----------|---------------------------|--------------|-----------|---------------------------|--------------|
| Al        | 1500 µg/L                 | EPA          | Ni        | 20 µg/L                   | WHO          |
| As        | 50 µg/L                   | EPA          | Pb        | 10 µg/L                   | WHO          |
| Ba        | 1000 µg/L                 | EPA          | Sb        | 0.6 µg/L                  | EPA          |
| Be        | 100 µg/L                  | EPA          | Se        | 10 µg/L                   | WHO          |
| Cd        | 3 µg/L                    | WHO          | Sn        | 2 µg/L                    | WHO          |
| Co        | 50 µg/L                   | WHO          | Sr        | 4000 µg/L                 | EPA          |
| Cr        | 50 µg/L                   | WHO          | Ti        | N/A                      | N/A          |
| Cu        | 2000 µg/L                 | WHO          | Th        | 2 µg/L                    | EPA          |
| Fe        | 300 µg/L                  | WHO          | V         | N/A                      | N/A          |
| Li        | 700 µg/L                  | EPA          | Zn        | 5000 µg/L                 | WHO          |
| Mn        | 10 µg/L                   | WHO          |           |                           |              |

WHO- World Health Organization, EPA- Environmental Protection Agency, BIS- Bureau of Indian Standards.

3.8.1. Ag, As, Be, Cd, Co, Pb, Sb, Se, Sn

Figure 9 shows the metal concentration variation among the selected lakes. Silver is found naturally on water and has antibacterial activity. The results are ranged from 0.05 to 1.79 µg/L and maximum concentration on Kurichi are under the control of the permissible limit of 70 µg/L (EPA). The concentration of the silver 1 mg/L will cause oxidative stress of the plankton and other water animals on the water [43]. The arsenic concentration of the sample ranged from 0.59 to 2.32 µg/L and falls behind the limitations of the EPA standard 50 µg/L. The arsenic toxicity causes cancer on skin, bladder, kidney and lung if exposed frequently, also affects the blood vessels on feet and legs [44]. The Beryllium concentration is very less from 0.02 to 0.37 µg/L as the minimum and maximum respectively. According to WHO 2009, Beryllium is a non-toxic element which will found rarely in drinking water and the guideline value is 100 µg/L.
concentration acquired in the Ukkadam lake is slightly higher and Valankulam lake is almost the same as the permissible limit of 0.6 µ/L (EPA). Antimony will available normally in the groundwater in the form Antimony (III, V), Where Antimony (III) is ten times toxic than others. The exposure of the toxicity will cause respiratory tract irritation, pneumoconiosis, skin spots, and gastrointestinal issues [46]. The Selenium concentration of the studies are absent in most of the lakes and 0.63 maximum in Valankulam is less than the permitted limit of 10 µg/L (WHO). The Tin concentration of tested water ranged from 0.20 to 1.10 µg/L is lesser than the limit of 2 µg/L (WHO).

3.8.2. Cr, Mn, Mo, Ni, Ti, Tl, V, Zn

Figure 10 shows the metal concentration difference between the selected lakes. The chromium concentration of the sample ranged from 1.75 to 7.13 µg/L and the concentration is lesser than the limitation of 50 µg/L (WHO). The chromium only occurs in the water bodies near to industries. It cannot be removed easily from water and only able to transfer from one group to another by oxidization. The chromium VI is toxic and it can be able to convert into chromium III which insoluble in water. Chromium leads to the destruction of vascular plants, unicellular algae, insects, amphibians and sensitive fishes [47].

The manganese concentration of the sample ranged from 0.47 to 2.86 µg/L. The concentration well under the limit of less than 10 µg/L (WHO). The manganese in water is the complex cycle which may undergo a complex cycle between oxidation states and species. The oxidation state is due to the activity of microbes and the level of dissolved oxygen in the water. The manganese concentration is maximum at the upper aerobic regions of surface water bodies. Naturally there manganese concentration is there in the water and suddenly increase in monsoon due to the surface runoff [48].
The Molybdenum analysis showed the results of 0.95 to 4.31 µg/L as minimum and maximum. The maximum permissible level is 10 µg/L (WHO). The nickel concentration in the samples is from 1.31 to 4.43 µg/L which is lesser than the WHO standard of 20 µg/L. It is a common element found in the water and soil in a lower concentration. Nickel in fresh and marine ecosystem is introduced maximum by anthropogenic activities [49]. The Titanium concentration ranged from 1.25 to 7.34 µg/L is very less than the limit of lesser than 100 µg/L [10]. The Thallium is ranged from 0.01 to 3.72 µg/L, which is higher than the limit of 2 µg/L (EPA). The concentration of Valankulam is higher. Thallium is a rare earth element which is normally found in the environment from chemical, electronic, medical, and aerospace and industries. The symptoms of human toxicity are vomiting, diarrhea, hair loss, nerve system damage, liver, kidney, heart, lungs and also death if the concentration exceeds the limit. Exposure to pregnant women causes detrimental on birth, fetal death, congenital deformities and underweight babies [50].

The vanadium of the test ranged 3.30 to 12.71 µg/L which less than the maximum permissible limit of 100 µg/L [13]. Zinc concentration is ranged from 2.33 to 21.17 µg/L as a maximum, which is under the limitation of 3000 µg/L (WHO). Zinc concentration in trace level is good and essential for the human diet. Zinc concentration in the water is mainly due to the drainage, urban runoff, erosion of soil and dumping of wastes. The recommendations of FAO and WHO are, drinking water above 3 mg/L concentration will cause undesirable astringent taste while drinking. The limitations of the irrigation are less than 2 mg/L and above this leads toxicities of plants and also pollute the aquifers [51].

3.8.3. Al, Ba, Fe, Li, Sr, Cu

Figure 11 shows the concentration deviation between the selected lakes. The Aluminium concentration of the tested sample ranged from 2.48 to 147.47 µg/L. the concentration of the Ukkadam is maximum compared to other lakes and under the limit 200 µg/L (WHO). It is the third most abundant element in the earth which occurs naturally in soil, water and air. The pH of the water and organic content is the main toxicity influencers of the aluminium. The toxicity will increase when the pH decreases. The increase in concentration leads to the mortality of aquatic animals and plants if it is used for irrigation [52].

The concentration of the Barium ranged from 36.91 to 257.35 µg/L and lesser than the permissible level of 1000 µg/L (WHO). It is an alkaline metal which is mostly for the industrial purpose and pesticide manufacturing. The Iron concentration of the samples ranged from 74.08 to 215.99 µg/L and under the limit of 300 µg/L (WHO). The excess concentration of iron leads to the cell and DNA damage ultimately destructs in the growth of the organism [53]. The lithium might have occurred due to the influx of huge sewage disposal that intrude in the lake water, Lithium bind with water closely, however, not covered in the essential element, and participated in human metabolism. Ignorable quantity of Lithium can affect the aquatic life form. The analysis of the samples showed the Lithium content as 98 µg/L to 386 µg/L range. EPA has set the maximum permissible limit to 700 µg/L. Strontium is were around 157.45 to 563.67 µg/L, which is less than the standard of 4000 µg/L (EPA). The copper concentration of the samples ranged from 10.30 to 29.88 µg/L and which is under the limitations of 20 µg/L (WHO). Its higher concentration causes serious environmental pollution like biodiversity and water quality loss [54].

In the current study, the sampling was done in pre-monsoon where the concentration of nutrients is high and the disposed domestic sewage dilution level is comparatively low due to the absence of rainfall. In the last decade, several examinations are made in the lakes of Coimbatore. Comparing the present study to earlier reports, the concentration exposes that, DO, BOD, COD, potassium, nitrate, Chloride, Turbidity, Alkalinity, Sulphate are multiple times higher in concentration [10,23,29,33]. When compared to the standards of WHO, EPA, BIS most of the samples are seems to be under the maximum permissible limit. The concentration of ORP, Alkalinity, BOD, COD, Fluoride, Phosphate, Turbidity, Chloride, Sodium and potassium concentration exceeds the limits. In heavy metal studies, the Singanallur lake shows the decreased concentration of Cu, Fe, Zn, Cd, Cr, Pb and Ni from the previous report by Meena 2015. The concentration of the Antimony and Thallium only exceeds the limit and other metals are under the limits.
The results of one-way Analysis of variance shows the physicochemical concentration in the order of Singanallur > Ukkadam > Valankulam > Selvachinthamani > Kurichi > Perur and for heavy metal analysis Valankulam > Ukkadam > Kurichi > Singanallur > Selvachinthamani > Perur from maximum to minimum.

4. Conclusion

Surface water is the main source of drinking for human and animals. Due to the rapid population growth and increased industrialization, the water bodies get deteriorated. The productivity of the surface water only depends upon the water quality. The dumping of waste into water leads to the increase of nutrients will increase the growth of microbe’s results in waterborne disease. In the aquatic ecosystem the good water quality help to the development, reproduction, and survival of plankton, flora, fauna, fishes, etc. The water also used for irrigation purposes, Current investigation reveals that among the examined selected lakes, Singanallur, Ukkadam, and Valankulam lakes are highly polluted compared with others. Singanallur and Ukkadam lake has been prone to heavy deterioration of water quality and sediment nature due to various diverse anthropogenic entities. To reduce this pressure on the lake, urgent attention is in need to conserve the elixir of life. A strong legislation clause is mandatory to conserve the lake and its water body quality with tight vigilant and people participated in efforts towards the safety of the lake would be a permanent solution.

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