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RESEARCH ARTICLE

A CASE STUDY ON VARTHUR LAKE, ASSESSMENT OF HEAVY METAL CONTAMINATION ON WATER AND COMPARATIVE WATER ANALYSIS

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ABSTRACT

The Process of urbanization is increasing at an alarming rate, putting more pressure on local water quality. The study was conducted to assess the water quality values of varthur Lake which is a major tank in varthur of Bangalore. The samples were collected to examine the water quality in the month of February-March 2018, and brought to the laboratory for Physico-chemical parameters analysis. The aim of this study is to assess the extent of heavy metal contamination of lake water due to influx of industrial and household wastes. Samples of water have been analyzed heavy metals oxides, viz. Halite, Illite, Feldspar, Indium, Boron, Kaolinite, Phosphorus and Cadmium using uv -vis absorption spectrophotometry and X-ray Diffraction analysis. The sample was evaporated off and the residue was subjected for x ray diffraction studies to identify the oxides of metals present looking at the peaks. The results show the presence of some of the heavy metals in the water sample beyond the limits of Indian standards. Subsequently the water samples of lake were collected and it was compared with the regular tap water of the campus. The toxicity level of such heavy metals has proven to be a major threat and there is several health risks associated with it. Even though they do not have any biological role in human body, but the toxicity of such metals remain present in some or the other harmful form for the human body and its proper functioning. They sometimes act as a pseudo element of the body while at certain times they may even interfere with metabolic processes. Despite of some conservation efforts made by the authorities the major lakes are threatening immeasurably. This project aims in bringing out the hazardous effect of such polluted lakes on environment and human health as whole.

INTRODUCTION

A lake is a large body of water surrounded by land, inhabited by various aquatic life forms, for all practical purposes, pure water is considered to that which has low dissolved or suspended solids and obnoxious gases as well low in biological life. The health of lakes and their biological diversity are directly related to health of almost every component of the ecosystem. Bangalore city is located over ridges delineating four watersheds, like Hebbal, Koramangala, Challaghatta and Vrishabhavathi watersheds (spanning over Bangalore north and south taluks). In 1961, the number of lakes and tanks in the city stood at 262. The built-up area in the metropolitan area was 16 % of total in 2000 and is currently estimated to be around 23-24 %. Official figures for the current number of lakes and tanks vary from 117 to 81, but recent remote sensing data gives a different picture altogether, showing only 33 lakes visible, out of which only about 18 are clearly delineated while another 15 show only faint signs of their former existence. The tanks were reclaimed for various purposes such as residential layouts, commercial establishments, sport complexes, etc.

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The wave like topography, featured by a series of valleys radiating from a ridge, forms three major watersheds, namely the Hebbal Valley, Vrishabhavathi Valley and the Koramangala and Challaghatta Valleys. All these make an important drainage system for the interconnected lakes which carries storm water beyond the city limits. Today, untreated sewage is also let into these storm water streams which progressively converge into these waterbodies. Varthur Lake is one such lake at the end of a chain of lakes. Varthur Lake, situated in the south of Bangalore, was built to store water for drinking and irrigation purposes. Due to the sustained influx of fresh sewage over a decade, nutrients in the lake are now well over safe limits. Varthur Lake has been receiving about 35-40% of the city sewage for over half a century resulting in eutrophication. There are significant algal blooms, Dissolved Oxygen (DO) depletion and malodour generation, and an extensive growth of water hyacinth. Sewage brings in large quantities of C, N and P which are trapped within the system. The various forms of nitrogen influent in sewage are organic N (protein N), urea, ammonia, nitrites and nitrates through processes like nitrification, denitrification and ammonification.

Heavy metals: Heavy metals are generally defined as metals with relatively high densities, atomic weights, or atomic numbers. The criteria used, and

whether metalloids are included, vary depending on the author and context. The earliest known common metals such as iron, copper, tin, and precious metals such as silver, gold, and platinum are heavy metals. Some heavy metals are either essential nutrients (typically iron, cobalt, and zinc), or relatively harmless (such as ruthenium, silver), but can be toxic in larger amounts or certain forms. Other heavy metals, such as cadmium, mercury, and lead, are highly poisonous. Heavy metals are relatively scarce in the Earth's crust but are present in many aspects of modern life. Trace amounts of metals are common in water, and these are normally not harmful to our health. In fact, some metals are essential to sustain life. Calcium, magnesium, potassium, and sodium must be present for normal body functions. Cobalt, copper, iron, manganese, molybdenum, selenium, and zinc are needed at low levels as catalysts for enzyme activities. Drinking water containing high levels of these essential metals, or toxic metals such as aluminum, arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver, may be hazardous to our health. One of the major symptoms of chemical toxicity seems to be a breakdown of the immune system, which opens the gateway for all kinds of diseases in the body. Also, another major symptom seems to be damage to the nervous system and increased nervousness. The young are more prone to the toxic effects of heavy metals, as the rapidly developing body systems in the fetus, infants and young children are far more sensitive. Childhood exposure to some metals can result in learning difficulties, memory impairment, damage to the nervous system, and behavioural problems such as aggressiveness and hyperactivity. With the advanced technologies today, in one elemental analysis run, multiple metals are often analyzed in multiple samples.

Objectives of study

1. To determine the baseline data of the physiochemical dynamics of varthur lake.
2. To carry out comparative water analysis.
3. To identify the heavy metals using uv-vis spectrophotometry and X-ray diffraction analysis.
4. To provide an overall outlook of the threat poses by such water bodies.

MATERIALS AND METHODS

BOD procedure: Water sample in BOD bottle was taken for estimation. 2 ml of each manganese sulphate and alkaline iodide azide was added in succession right at the bottom of the bottle with separate pipettes and stopper is replaced. The bottle was shaken in upside down direction for at least 6 times. a brown precipitate was formed and allowed to settle. Then 2 ML concentrated sulphuric acid was added and stopped bottle was shaken to dissolved the precipitate 50 ml of the solution was taken in a conical flask and titrated against sodium thiosulphate solution till the color changes to paint straw. 2 ML starch solution was added to the above flask and color of the contents changes to blow the above solution was titrated again against sodium thiosulphate till the color changes from Blue to colorless the process was repeated for concordant readings.

Calculation:

$$\text{DO in mg/L} = \frac{8 \text{ X } 1000 \text{ X N X } V_1}{V_2}$$

$$\text{BOD} = DO_1 - DO_5 \text{ mg/L}$$

Where,
DO_1 = Dissolved oxygen value of day 1
DO_5 = Dissolved oxygen value of day 5

COD procedure: Pour 50 ml water in conical flask can take 50 ml water in another flask. Pour 5 ml potassium dichromate solution in each flask and incubate them at 100°C for 1 hour in water bath. Remove the flask to cool for 10 minutes and mix 5 ml KI solution and 10 ml sulfuric acid in each flask. Titrate this solution with sodium thiosulphate till the pale yellow color disappears and note the burette reading. Add 1 ml of starch solution and the color turns blue. Titrate again against sodium thiosulfate till blue color disappears completely.

Calculation:

Calculate the COD of water using following formula:

$$\text{COD (mg/L)} = \frac{8 \text{ x C x } (Vb - Va)}{V_S}$$

Where,
C = Concentration of titrant
V_a = Volume of titrant for control
V_b = Volume of titrant for water sample
V_s = Volume of water sample taken

Nitrate test: A common nitrate test, known as the brown ring test can be performed by adding iron sulfate to a solution of a nitrate, then slowly adding concentrated sulfuric acid such that the acid forms a layer below the aqueous solution. A brown ring will form at the junction of the two layers, indicating the presence of the nitrate ion.

UV-vis spectrophotometric analysis: Spectrophotometer is a tool that hinges on the quantitative analysis of molecules depending on how much light is absorbed by coloured compounds. There are two major classes of devices, single beam and double beam. A double beam spectrophotometer compares the light intensity between two light paths, one path containing a reference sample and the other the test sample.

Reference Sample – Distilled water.
Test Sample – Lake Water

Below mentioned intensity is set each time for each of the different metals detection, reading is observed in the computer.

XRD analysis: X-ray powder diffraction analysis (XRD) is perhaps the most widely used X-ray based analytical techniques for characterizing materials. When an X-ray beam hits a sample and is diffracted, we can measure the distances between the planes of the atoms that constitute the sample by applying Bragg's Law. X-rays are diffracted by each mineral differently, depending on what atoms make up the crystal lattice and how these atoms are arranged. Bragg's Law is: $n\lambda = 2d \sin\theta$, where the integer 'n' is the order of the diffracted beam, 'λ' is the wavelength of the incident X-ray beam, 'd' is the distance between adjacent planes of atoms (the d-spacings), and is the angle of incidence of the X-ray beam. The geometry of an XRD unit is designed to accommodate this measurement. The characteristic set of d-spacings generated in a typical X-

ray scan provides a unique "fingerprint" of the mineral or minerals present in the sample. When properly interpreted, by comparison with standard reference patterns and measurements, this "fingerprint" allows for identification of the material. Water sample is boiled till the water part is evaporated, and the dried scraps are collected which are in powder form. The solid powder is used as a test sample for the XRD analysis.

Steps involved in procedure:

- Sample Preparation
- Safety Measurement
- Analysis of Data
- Peak Identification

Results are commonly presented as peak positions, the peaks are matched with a set database which helps in identification of unknown metals.

RESULTS

The water sample in the month of February-March'18 was collected and the experiments were simultaneously carried out. Dissolved Oxygen (DO) is the amount of oxygen dissolved in lake water. Oxygen is necessary for all living organisms to survive except for some bacteria. Living organisms breathe in oxygen that is dissolved in the water. The amount of oxygen lake water can hold is directly related to temperature. The colder the water, the more dissolved oxygen it can hold. Dissolved oxygen is supplied to a lake from two main sources: plant and algae photosynthesis and diffusion from the atmosphere. In photosynthesis, plants use the sun's energy to convert carbon dioxide and water into oxygen and cellular material (growth). Because there is a higher concentration of oxygen in the atmosphere (air) than water, oxygen diffuses into the surface of the lake from the atmosphere (Table 4). **B**iological Oxygen Demand (BOD) determines the strength of organic waste (sewage effluents and other pollutants) in water and provides data on the pollution load in all natural water bodies. High values of BOD values in Varthur lake i.e 72mg/L (Table 4) water may be due to agricultural and domestic discharge in the lake. **C**hemical Oxygen Demand (COD) around 150-160 mg/L.(Table 4) COD test provides an index to assess the effect discharged wastewater will have on the receiving environment. Higher COD levels mean a greater amount of oxidizable organic material in the sample, which will reduce dissolved oxygen (DO) levels. A reduction in DO can lead to anaerobic conditions, which is deleterious to higher aquatic life forms. COD level can increase due to increased household wastewater and waste discharges.

Heavy metals detection by uv-vis spectroscopy

Based upon the uv-vis spectrophotometric analysis data, qualitative analysis (ring test) for nitrate was carried out. The image obtained is as follows. Methemoglobinemia is the most significant health problem associated with nitrate in drinking water. Blood contains an iron-based compound called hemoglobin, which carries oxygen. When nitrite is present, hemoglobin can be converted to methemoglobin, which cannot carry oxygen. Children under the age of six months are more prone to developing methemoglobinemia, or blue baby syndrome, when consuming high-nitrate water. The sample was then subjected to allowed for XRD analysis. The graph obtained was as follows:

The x ray diffraction was carried out after drying off the sample and the residue was subjected in XRD for a time period of 1 hour 45 minutes.

Table 1. List of equipments

EXPERIMENTS	REQUIREMENTS
Dissolved oxygen, biological oxygen demand and chemical oxygen demand.	BOD bottles, incubator, test tubes, beakers, conical flask.
pH	pH meter
Temperature	Thermometer
Electrical conductivity	Voltmeter
Qualitative analysis of nitrate.	Test tubes, bunsen burner
Uv-vis spectrophotometric analysis.	Uv-vis spectrophotometer
XRD analysis	XRD machine

Table 2. Absorbance of each materials.

Iron	510nm
Manganese	525nm
Aluminium	535nm
Boron	540nm
Fluoride	570nm
Nitrate	543nm
Indium	495nm
Silicate	815nm
Phosphorus	880nm
Ammonia	640nm

Note: For the graphical representation light intensity range is set from 400nm-950nm, which gives the result.

Table 3. Physical characteristics of lake water sample

Parameters	Standard value	Sample value
Colour	Colour less	Greyish black
pH	7.0	7.68
Odour	No smell	Offensive
Total Hardness	120-180 mg/L	232.5 mg/L
Temperature	23-30^{o}C	26^{o}C

Table 4. Results of Physico-chemical analysis of lake water sample

Parameter	Unit	Standard value	Sample value
DO	mg/L	3-5 mg/L	2.9 mg/L
BOD	mg/L	60-90 mg/L	72 mg/L
COD	mg/L	180-250 mg/L	155.5 mg/L

Table 5: Results of uv-vis spectroscopy

Metals	Wavelength	Tap water	Sample water
Iron	510nm	0.001	0.153
Manganese	525nm	-0.000	0.144
Aluminium	535nm	-0.001	0.133
Boron	540nm	-0.000	0.193
Cadmium	530nm	-0.002	0.131
Nitrate	543nm	-0.001	0.141
Indium	495nm	NA	0.161
Silicate	815nm	0.001	0.091
Phosphorus	880nm	0.001	0.081
Ammonia	640nm	-0.003	0.115

The oxides of metals was detected using the software x'pert high score plus. The oxides of metal most prominent in the graph were found. The graph obtained is as follows. Indium is a soft, silver-white metal used in manufacturing. It is chemically similar to aluminum and gallium. Indium's most common industrial use is in the production of electrodes used in liquid crystal displays (LCDs). The presence of Indium in lake water can be threatening for the nearby surroundings.

Fig. 1. Lake normal water flow

Fig. 2. Toxic foam formation

Fig. 3. Sample is collected in BOD bottles (no air bubble)

Fig. 4. Sample with Alkali-Iodide-Azide

Fig. 5. Addition of Sulphuric acid

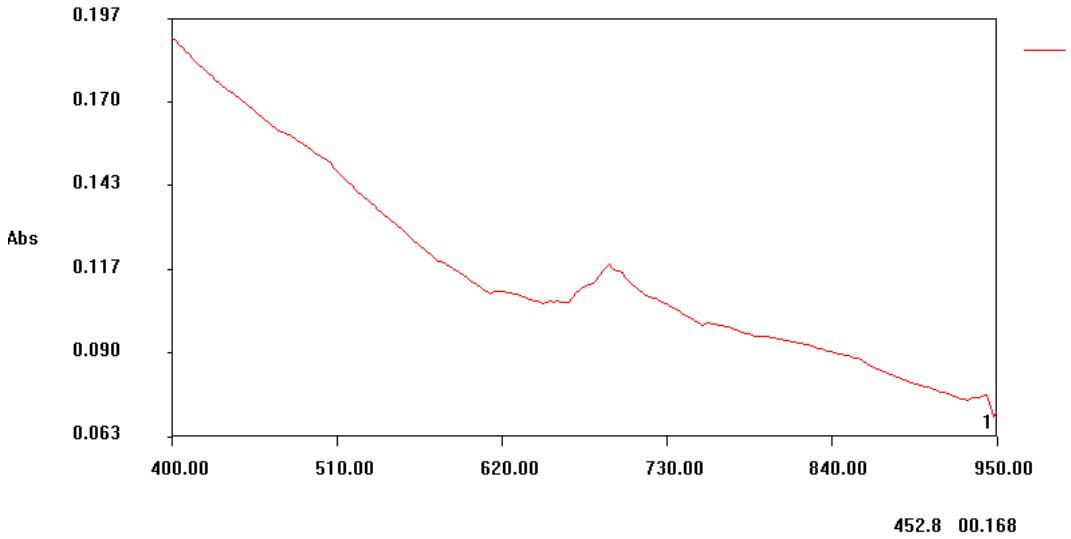

Fig. 6: Graph plotted by Spectrophotometer

Fig. 7: Ring test for confirmation of nitrogen presence

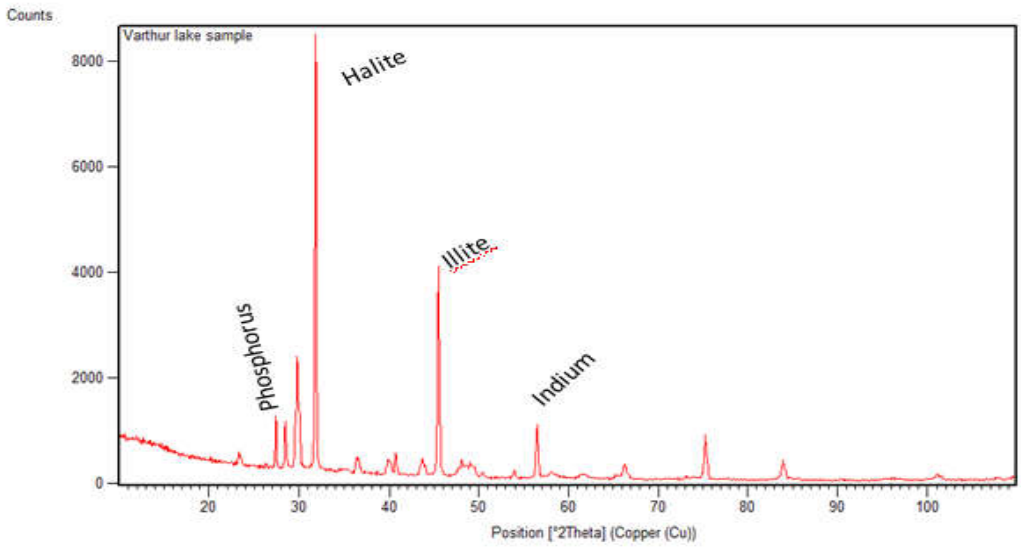

Fig 9: XRD pattern of water sample collected from Varthur Lake

Fig. 10. Varthur Lake on Google Earth

Fig. 11. Solid wastes dumped in the lakes bed

Fig. 12. Coir blocks placed at the weir of lake to suppress frothing

As of now the toxic effect of indium on humans is very little known, but indium ions can be toxic to the kidney, Indium tin oxide and indium phosphide harm the pulmonary and immune systems. Chloride (Cl-) is completely soluble and very mobile. Chloride is toxic to aquatic life and impacts vegetation and wildlife. The transport of sodium (Na+) in the environment is not as prominent as chloride due to ion exchange, however Halite can alter the soil chemistry by replacing and releasing nutrients into the groundwater and surface water changing soil structure and impacting the aquatic environment. Contamination of sodium in drinking water is a concern for individuals restricted to low-sodium diets due to hypertension. Wildlife is also prone to high sodium levels. Cadmium occurs naturally in ores together with zinc, lead and copper. Cadmium compounds are used as stabilizers in PVC products, colour pigment, several alloys and, now most commonly, in re-chargeable nickel–cadmium batteries. Cadmium production, consumption and emissions to the environment worldwide have increased dramatically during the 20th century. Cadmium containing products are rarely re-cycled, but frequently dumped together with household waste, Cadmium exposure may cause kidney damage. The IARC (International Agency for Research on Cancer) has classified cadmium as a human carcinogen (group I).

Summary: Water pollution is on the rise all over the world. Much of it is down to anthropogenic stress/activities. The lake has a huge impact on the health of local people, plants and animals. Lakes often contain high pollution levels relative to the surrounding landscapes and environment. Rivers and streams drain pollutants from the landscape, where they concentrate in lakes and other similar water bodies.

Conclusion: The study reveals that sewage is the main source of pollution of this water body and irrigation with sewage contaminated water containing various heavy metals leads to high concentration of heavy metals deposition in surrounding soil and vegetation. The growth and spread of macrophytes renders the lake anaerobic condition and reduces its capacity to treat the water. Keeping an open surface and permitting microalgal growth provides a high level of water treatment, and it may be used in a large scale for varthur and similar lakes in Bangalore and other cities in India.

Future scope of the study (Importance of the study): The immediate importance of the study is to alert the Bangalore Development Authority and the local people about the need to save water body and explain the leaching and accumulation of nutrients.

The research carried out would enable the potential for advanced engineered biological systems for large scale bioremediation of lakes and local water bodies from pollutants.

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