Asian Journal of Water, Environment and Pollution, Vol. 21, No. 6 (2024), pp. 9-14.
DOI 10.3233/AJW240067

Assessing Water Quality in the Cooum River Basin: A Comprehensive Review of Methodologies and Findings

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Received January 25, 2024; revised and accepted June 26, 2024

Abstract: Water is a precious and essential resource for sustaining life on Earth, and its economic importance cannot be overstated. Groundwater pollution can occur from a variety of sources, including industrial activities, agricultural practices, landfills, waste disposal sites, underground storage tanks, sewage treatment plants, septic systems and natural sources. With rapid growth in industrial sectors and population, the amount of waste and pollutants being discharged into the river has increased, causing adverse impacts on the ecosystem and human health. This review article summarises the different approaches utilised to assess the water quality and to examine the trace metal contamination in Cooum river basin. This article highlights the challenges associated with assessing water quality in the Cooum River basin due to the high levels of pollution caused by anthropogenic activities such as industrialisation, urbanisation, and agricultural practices. The article reviews the chemical variation of pollutants and their seasonal effects, specifically focussing on the release of microplastics, polycyclic aromatic hydrocarbons (PAHs), and heavy metals in water bodies. This article conducts a systematic analysis and summary of the physico-chemical properties of Cooum river. Further research on hydrochemistry will yield valuable information on water quality that can lead to effective water resource conservation. Overall, this review article provides a useful summary of the different approaches used to assess water quality and examine trace metal contamination in the Cooum River basin. It highlights the importance of continued research in this area to better understand the extent of pollution and its impact on the ecosystem and public health.

Key words: Cooum river, physico-chemical analysis, trace element concentration, seasonal variation, risk assessment.

Introduction

Rivers have a significant impact on shaping the ecological environment of a basin and also play a crucial role in the global water cycle. Despite the earth's surface being covered with 75% water, people continue to suffer due to a lack of access to potable water. The river quality is influenced significantly by environmental factors such as rainfall, temperature, weathering of rocks, and anthropogenic activities. However, the major cause is the discharge of untreated industrial and domestic wastewater (Aishwarya et al., 2014a, 2014b; Aishwarya et al., 2023). The rapid industrialisation and urbanisation in Chennai resulted in significant waste generation (Brown et al., 1970; Clesceri et al., 1998). The high population density in Chennai puts pressure on the drainage system and sewage treatment plants, and the current system is incapable of handling the significant domestic discharge, causing the degradation of the Cooum river. Fertilisers and pesticides are significant contributors to water pollution, and they result in the presence of several

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chemical pollutants in water such as heavy metals, microplastics, plasticizers, hydrocarbons, and pesticides. This chemical modification is influenced by multiple factors, such as the groundwater residence duration, solid phase interaction, mixing with saline water pockets, seepage of polluted water, and anthropogenic activities. The Cooum River, located in the southern part of India, is known for its high pollution levels (Davina et al., 1999; Dhamodharan et al., 2016; Elangovan and Dharmendirakumar 2013; Etier et al., 2020; Govindaraj et al., 2022). Besides the presence of untreated waste discharge, the river also contains heavy metals that are toxic and can be harmful to human health. Heavy metals like lead, cadmium, mercury, and arsenic are known to cause severe health problems like cancer, neurological disorders, and damage to vital organs like the liver and kidneys. Water quality may be evaluated using physicochemical factors including pH, dissolved oxygen, biochemical oxygen demand, and total dissolved solids. These parameters give an idea of the level of organic and inorganic substances present in the water, which can affect aquatic life and human health (Govindaraj et al., 2023a, 2023b, 2023c).

Groundwater Quality in Cooum River, Chennai

Human activities can introduce harmful substances into groundwater, which is referred to as groundwater contamination and can result in it being unsuitable for various purposes. Although numerous types of pollutants can be identified in groundwater, chemical and biological pollutants are deemed the most significant. These contaminants can originate from both natural and human activities. Due to the substantial quantities of nitrogen, phosphorus, and heavy metals that penetrate the soil and subsequently enter the groundwater through rainfall and irrigation, anthropogenic activities pose an escalating threat to the quality of groundwater (Karunanidhi et al., 2021; Kavitha et al., 2023; Mohamed Sheriff and Zahir Hussain, 2012).

The review matrix is crucial in providing an overview of the number of completed studies within the specified timeframe, which can help understand the extent of groundwater contamination in the Cooum River Basin. The studies were classified based on the four core categories, offering a glimpse of the kind of research required in the future. Without proper environmental management of pollution sources, it is impossible to ensure adequate groundwater quality. Conducting more water quality studies over a prolonged period is necessary to guarantee the sustainability and availability of freshwater sources in the future. It is beneficial to have water quality monitoring data for a few years at least to compare ion concentrations over time (Ramesh et al., 2002; Ravisankar and Poogothal, 2008; Rowell, 1994).

Sources of Groundwater Pollution in Cooum River, Chennai

One of the major sources of pollution in the Cooum River is domestic sewage. The sewage generated from households and industries is directly discharged into the river, which leads to high levels of contaminants such as nitrogen and phosphorus in the water. These nutrients can lead to eutrophication, which causes the growth of harmful algal blooms and depletion of oxygen levels in the water, leading to the death of aquatic life (Siosemarde et al., 2010; Trivedy and Goel, 1986; Venkatesan and Subramani, 2018).

Industrial effluents are another significant source of pollution in the Cooum river. Many industries located near the river discharge their untreated wastewater into the river, containing harmful chemicals such as heavy metals, organic compounds, and acids. These pollutants are not only toxic to aquatic life but can also pose a risk to human health when consumed through contaminated water (Venkatesan and Subramani, 2019; Venkatesan et al., 2020c; Venkatesan and Subramani, 2022a; Venkatesan et al., 2022b). The discharge of industrial effluents into the river has resulted in the accumulation of heavy metals such as lead and nickel in the sediment and water.

Factors Involved in Analysing Water Quality Parameters

The assessment of water quality and examination of trace metal contamination was conducted through a comprehensive methodology encompassing various parameters and standard analytical techniques.

Data analysis involved the examination of results obtained from 30 sampling sites within the Cooum River basin across two distinct sampling periods to assess seasonal variations in chemical compositions. The methodologies employed adhered to established standards for sample collection, preservation, and analysis (Venkatesan et al., 2023).

For the quantification of key parameters, instruments and techniques specific to each parameter were utilised. pH and conductivity measurements were conducted using calibrated pH and conductivity meters, respectively. The concentrations of Na+ and K+ were determined employing a flame photometer, while Silica content was assessed utilising the molybdate blue method. Furthermore, nitrate, nitrite, phosphate, and fluoride concentrations were measured employing an ultraviolet-visible spectrophotometer. Chloride concentrations were estimated through $AgNO_3$ titration, while sulfate analysis was performed using the turbidimetric method.

In accordance with Elangovan et al. (2013), specific water quality parameters including pH, electrical conductivity, sodium, and lead were assessed using appropriate techniques such as pH meter, conductivity meter, an evaporation method, modified Winkler's method, titration with an excess of $K_2Cr_2O_7$, flame photometry, and atomic absorption spectrometry, respectively. The obtained results were compared against the permissible limits stipulated by the World Health Organization.

Moreover, samples collected underwent a comprehensive testing regime for various physical and chemical parameters as per the protocols established by the Tamil Nadu Water Supply and Drainage Board (TWAD). These parameters included appearance, odour, turbidity, total dissolved solids, pH, and alkalinity.

Physical Parameters

pH

The pH of water indicates the amount of hydrogen ions (H+) present in it. When the pH value of water is less than 7, it is classified as acidic, while water with a pH value above 7 is considered to be basic or alkaline. According to the WHO, the pH range of water that is safe for the protection of fish and aquatic life is between 6.0 and 9.0. Experimental analysis of water samples conducted during the pre-monsoon period showed pH values ranging from 6.71 to 8.31, while during the post-monsoon period, the pH values were between 6.6 and 7.7. These experimental values fall within the recommended pH limits set by the WHO. These findings suggest that the pH levels of the analysed water samples are not harmful to domestic and aquatic systems.

The elevated pH levels observed during the pre-monsoon period suggest contamination of surface water, possibly due to infiltration of groundwater. The mean pH values of 7.548 ± 0.36026 and 7.2545 ± 0.284225 during the pre-monsoon and post-monsoon seasons, respectively, indicate a slightly alkaline nature of the water. This could be attributed to the seepage of wastewater from domestic and industrial sources.

Electrical Conductivity

Electrical conductivity refers to the degree of ionised substances present in water that can conduct an electric current. The level of electrical conductivity is an indication of the strength of the current flow based on the quantity of dissolved salts present in the water. In this study, the electrical conductivity values of the water samples fell within a range of 498 to 2371 μS/cm and 508 to 2207 μS/cm during varied seasons. During the study period, the analysis indicates a steady increase in the levels of electrical conductivity, which in turn enhances the concentration of ionized substances in the water. The highest variation in the electrical conductivity values was observed during the pre-monsoon season, with a coefficient of variation percent of 42.11, which was higher than that observed during the post-monsoon season with a coefficient of variation percent of 33.3672.

Total Dissolved Solids (TDS)

TDS refers to the concentration of both cations and anions present in water. The major constituents of TDS include bicarbonate (HCO_3^-), sulphate (SO_4^{2-}), hydrogen (H^+), silica (SiO_4), chlorine (Cl^-), calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^+), potassium (K^+), nitrates (NO_3^-), and phosphates (PO_4^{3-}). The TDS levels observed in the groundwater are primarily a result of vegetable decay and the discharge of industrial effluents. The TDS values of the water samples collected during the pre-monsoon season ranged from 987 to 2892 mg/L, while during the post-monsoon season, the TDS levels were found to be between 905 and 2716 mg/L.

Chemical Parameters

Dissolved Oxygen (DO)

The dissolved oxygen levels observed in all the groundwater samples ranged from 6.5 to 8.5 parts per million (ppm). While low DO values were recorded in one station, two other stations showed high DO levels. These variations may be attributed to the physical and biological processes that occur naturally in water bodies. The changes in DO concentration observed in different stations are primarily influenced by fluctuations in temperature and BOD (biological oxygen demand). This is because the solubility of dissolved oxygen increases with a decrease in water temperature, as noted by previous studies. Additionally, the decomposition of organic matter by microorganisms can enhance the DO content in water.

Total Hardness

The total hardness values observed in the groundwater samples ranged from 156 to 286 ppm. These values were found to be within the permissible limit of 300 ppm for all stations. Based on classifications by some standards, water with hardness up to 75 ppm is considered soft, 76 to 150 ppm is moderately soft, 151-300 ppm is hard, and values exceeding 300 ppm are considered very hard. Accordingly, the results of this study indicate that all the samples were classified as moderately soft.

Nitrite (NO_2)

Nitrite levels were measured to be between 0.01 and 0.08 ppm, which is well below the maximum allowable limit of 45 ppm. However, the samples collected closer to the river exhibited higher nitrite levels than those collected further away, possibly due to factors such as percolation of river water, dumping of garbage, sewage leakage from septic tanks, and open defecation by humans and animals.

Sulphate (SO_4)

The concentrations of sulphate in the groundwater samples ranged from 36.71 to 94.91 ppm, which falls within the permissible limit of 250 ppm. The high concentration of sulphate in groundwater can be attributed to various factors such as the accumulation of soluble salts in soil, anthropogenic activities, and excessive use of sulphate fertilizers. Sulphate deficiency does not usually cause any symptoms. However, most people obtain the majority of their dietary sulphates from food rather than from water. Elevated levels of sulphate in water, such as 1000 mg/L, have been found to have a laxative effect on humans and can cause mild gastrointestinal irritation. The allowable limit for sulphate concentration in drinking water is 400 mg/L.

Chloride (Cl)

The recorded values of chloride in groundwater samples range from 328 to 1509 ppm. Chloride is a significant inorganic anion commonly found in natural water sources. The presence of chloride in water can be attributed to various sources such as agricultural activities, domestic sewage, and rocks rich in chloride. Additionally, the human body also releases a significant amount of chloride. Elevated levels of chloride in water can indicate pollution from high concentrations of organic waste from industrial or animal sources.

Microplastic Analysis (FTIR - SEM)

To confirm the presence of plastics in the effluent samples, they undergo FTIR analysis. Following this, the samples are subjected to SEM analysis to visually observe the plastics present on the filters. Out of the 30 samples collected, 14 were found to contain microplastics. Among these 14 samples, 4 of them had both primary and secondary microplastics. Primary microplastics, which are mainly spherical pellets or beads used in packing materials, were detected in smaller quantities than secondary microplastics. It is possible that the primary microplastics ended up in the water sources due to deposition in rivers. On average, the samples were found to contain 9.075% of waste materials, including shells, organic matter, plastics, food waste, and other types of litter. The plastic component was found to be very small, comprising only 0.012% of the sample's weight.

Heavy Metal Analysis

The metal content present in the deposits of the Cooum river is influenced by urbanization and shows varying behaviours. Study shows the distribution of heavy metals in both the base deposit and water samples of the river. The total metals present in the deposits, which are less than 20 mm in size, ranged from 45 to 497 mg/kg for Arsenic, 19.7 to 438 mg/kg for zinc, 12.3 to 59.39 mg/kg for copper, 0 to 30.6 mg/kg for lead, 0.7 to 24.4 mg/kg for cadmium, and 0.01 to 0.79 mg/kg for mercury.

Integrated GIS Analysis

This study used ARC GIS to analyse the mass transfer of contaminants, including nutrients and trace metals, from the Adyar and Cooum Rivers, which run into the Bay of Bengal in Chennai, Tamil Nadu. A recent base map of Chennai city at a 1:50,000 scale was generated using IRS-1D LISS-III, and the predicted concentrations of pollutants was entered into the spatial modeller of ARC VIEW and ARC GIS. The obtained data were then superimposed on the base map to investigate the impact of river discharges on the coastal environment. The Cooum River discharge ranged from 266.45 to 709.34 × 106 litres per day. The Cooum River's low discharge can be ascribed to severe silt deposition induced by storm water drains and the building of Kesavaram and Aranvayal anicuts over the river, which restricts upstream flow. Furthermore, the mouth of the Cooum River is frequently closed due to sand bar development caused by the construction of the artificial Chennai harbour.

Summary

This paper aims to review the past, present, and future aspects of water quality assessment, leading to a systematic review of various articles related to water quality assessment in and around Cooum river basin. The assessment includes an evaluation of the advantages and limitations of existing approaches and a discussion of the same. The review concludes that the Cooum river is contaminated and not suitable for domestic, irrigation, or aquaculture purposes due to high levels of heavy metals, particularly copper and manganese, which pose a medium risk to the environment. Nickel and lead levels show high risk at multiple stations in the middle and lower parts of the river, mainly due to the mixing of industrial and domestic effluents. However, chromium and iron were found to have minimal impact.

Cluster analysis identified seasonal variations, with the upper part of the river being less polluted than the middle and lower parts influenced by anthropogenic activities such as sewage discharge, silicate-weathering reactions, and saline water intrusion. Elevated levels of plasticizers and BPA in the sediments of the rivers were primarily attributed to the discharge of industrial and household wastewater, as well as the burning of plastic waste along the riverbanks, with e-waste sites showing the highest concentrations of these contaminants. These findings highlight the urgent need for proper waste management practices and effective measures to control industrial and domestic wastewater discharge to protect the Cooum river ecosystem and its surrounding communities.

Other remedial measures include implementing strict enforcement of environmental regulations; industries are required to implement pollution control technologies and treatment methods. They are further conducting regular monitoring and assessment to track progress and ensure that the implemented remedial measures are effective in mitigating the contamination.

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