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Analysis of a few heavy metals in Buckingham Canal water, Chennai, Tamil Nadu, India

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Abstract
Rapid industrialization has led to contamination of natural water with heavy metals due to dumping of untreated wastes into the aquatic habitats. The accumulation of metals in an aquatic environment has direct consequences to man and to the ecosystem also. These heavy metals are toxic pollutants, non-biodegradable and present the cumulative effect to the food chain, threatening human and animal health. Environmental pollution, particularly water pollution by toxic heavy metal is the result of several industrial activities, and its control has been a challenge. Therefore, in the present study the water samples of Buckingham canal, Chennai, Tamil Nadu, India were analyzed for the presence of heavy metals from March 2011 to February 2012. The heavy metal analysis of Buckingham canal water samples revealed that some of the heavy metals analyzed were above the toxic metal permissible limit. Chromium, copper, iron, lead and zinc values ranged from 0.006 to 0.012, 1.04 to 1.34, 0.23 to 1.75, 0.013 to 0.035 and 0.125 to 1.6mg/L respectively. Heavy metal pollution affects not only aquatic organisms, but also public health as a result of bioaccumulation in food chain. Therefore, contamination of freshwater with heavy metals causes devastating effect on ecological balance of the aquatic environment and on the other hand the diversity of aquatic organisms becomes limited with the extent of pollution.

Keywords: Buckingham Canal, heavy metals, chromium, copper, iron, lead, zinc

1. Introduction

Toxicity is the inherent property of a chemical molecule to produce injury on reaching a susceptible site on or in an organism. Human beings, animals and plants are continually being exposed to various chemical pollutants in the environment. Heavy metals are being passed on into aquatic environment through industrial processes, sewage disposal, soil leaching and rainfall. The concentration of these heavy metals is sub-lethal or lethal to aquatic organisms when the duration of exposure to these metals are prolonged [1]. It is well documented that the effect of heavy metals are dependent upon the physical and chemical conditions of the environment especially water salinity, hardness, pH and dissolved oxygen and can act synergistically. Rapid industrialization has led to contamination of natural water with metals due to dumping of untreated wastes in the aquatic habitats [2]. The accumulation of metals in an aquatic environment has direct consequences to man and to the ecosystem also. Although, trace metals are essential for normal physiological process, abnormally high concentrations can be toxic to aquatic organisms [3]. Heavy metals being non-biodegradable primarily necessitate knowledge on their uptake, distribution and persistence in tissues of organisms [4]. These heavy metals are toxic pollutants and non-biodegradable and present the cumulative effect to the food chain, threatening human and animal health. Environmental pollution, particularly water pollution by toxic heavy metal is the result of several industrial activities, and its control has been a challenge. Therefore, in the present study the water samples of Buckingham canal, Chennai, Tamil Nadu, India were analyzed for the presence of heavy metals.

2. Materials and Methods

2.1 Study Area

Chennai (Madras) the capital of Tamil Nadu is situated on the eastern coast of India (13.0827° N, 80.2707° E). There are three water ways that flows through the city, *viz*., Cooum river, Adayar river and Buckingham canal. The Buckingham canal is a man-made water canal linking the two rivers, Cooum and Adayar. The portion north of the Cooum is known as the north Buckingham canal, and the portion south of the Cooum as the south Buckingham canal. The canal extends from Nellore in Andhra Pradesh to Marakkanam near Puducherry. The length of this canal in Andhra Pradesh is 257km, and 163km is in Tamil Nadu. Approximately, 31km is within the city limits of Chennai (Figure 1). The canal was known as Lord Clive's canal and later as Buckingham canal. However, the section in Chennai was known as Cochrane's canal for much of the 19th century. The Cooum connects the canal to the Bay of Bengal in the center of Chennai.

Within the city of Chennai the canal is badly polluted from sewage and industrial effluents, and the silting up of the canal has left the water stagnant, creating an attractive habitat for mosquitoes. The North Chennai Thermal Power Station (NCTPS) discharges hot water and fly ash into the canal as well. Within the city limits of Chennai much of the canal has been used as the railway route of the elevated Mass Rapid Transport System (MRTS). MRTS stations, *viz*., Kotturpuram, Kasturbai Nagar and Indira Nagar have encroached the canal and narrowed its width to less than 50m in few places. Buckingham canal is the most polluted of the three major waterways in the city with nearly 60% of the estimated untreated sewage being let into it daily, including Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB). The water quality is considered to be highly toxic and completely non-potable. The three waterways are severely polluted in Chennai city, particularly the Buckingham canal by sewage, sullage, industrial wastes, storm water drainage and garbage, as a result of haphazard urbanization.

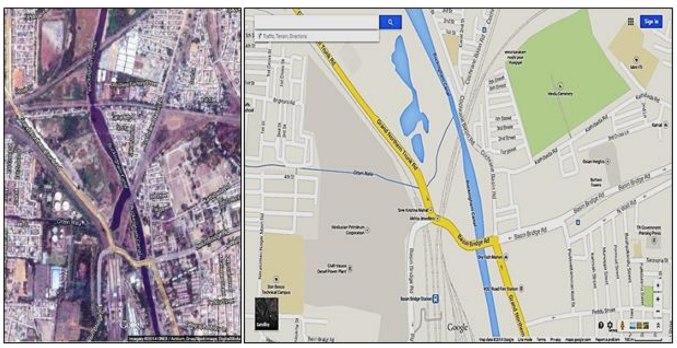

Fig 1: Study area-Buckingham canal

2.2 Collection and analysis of water samples

The water samples were collected on a monthly basis in triplicate from the study site from March 2011 to February 2012. On the canal side, the water samples were collected at a depth of 2 to 4m from each site. The water samples were analyzed for heavy metals, *viz*., chromium, copper, iron, lead and zinc. The estimation of heavy metal concentration in the collected water samples was done based on the liquid–liquid extraction procedure [5] using Perkin Elmer ICP-MS ELAN DRC equipment.

3. Results

The values for heavy metals present in Buckingham canal water during the study period from March 2011 to February 2012 are presented in Figure 2. The heavy metal analysis of Buckingham canal water samples revealed that some of the heavy metals analyzed were above the permissible limit. Chromium, copper, iron, lead and zinc values ranged from 0.006 to 0.012, 1.04 to 1.34, 0.23 to 1.75, 0.013 to 0.035 and 0.125 to 1.6mg/L respectively.

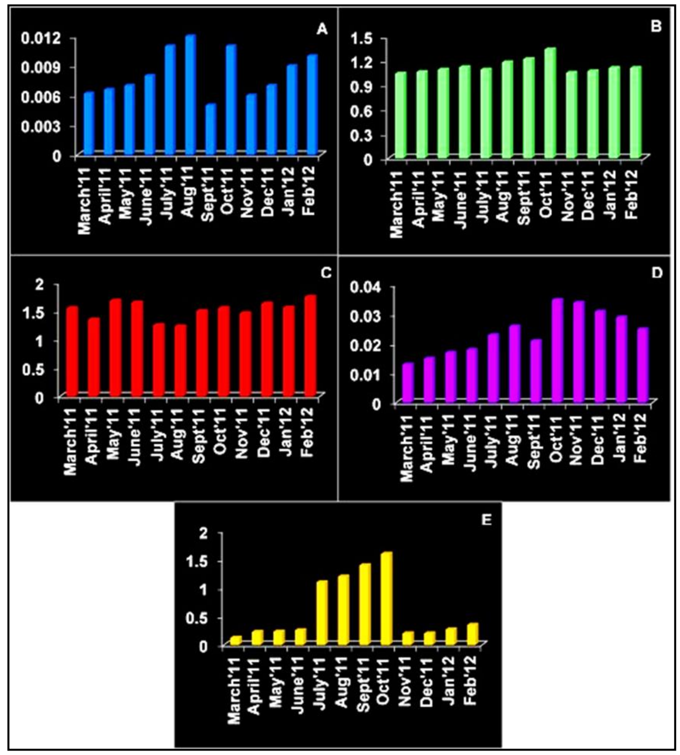

Fig 2: Heavy metals analysis of Buckingham canal water (all values in mg/L). **A:** chromium; **B:** copper; **C:** iron; **D:** lead; and **E:** zinc

4. Discussion

Wide use of heavy metals by the industrial, agricultural and domestic sectors results in release of toxic pollutant in the environment posing a serious threat to the aquatic animals. Heavy metals in the aquatic ecosystem often show levels above the expected values. The heavy metals, *viz*., mercury, chromium, copper and zinc are potent toxicants and cause various physiological effects on growth, food intake, metabolism and general development of aquatic animals [6]. Heavy metals may cause damage to organs as a result of significant alterations in various metabolic activities. The aquatic organisms exposed to several environmental factors may reflect adaptive metabolic mechanisms due to the challenges of the changing environment including the pollutants [7].

Chromium is an environmentally significant metal used in various industrial processes [8]. The values of chromium in the present study ranged from 0.006 to 0.012mg/L. The WHO limit is 0.1mg/L. Chromium compounds enter natural water mainly through the effluents from electroplating and tanning industries, from dyeing, from sanitary, land fill leaching and from water-cooling towers and can also enter the drinking water distribution system from the corrosion inhibitors used in water pipes [9]. Nearly 90% of all leather produced is tanned using chromium and its determination in environmental samples is of great importance due to its toxicity. Chromium is reported to have a toxic effect on humans [9]. It significantly differs in biological, geochemical and toxicological properties [10,11], even though it is considered essential for mammals for maintenance of glucose, lipid and protein metabolism. The tannery effluents, rich in suspended and dissolved impurities plus toxic chemicals have been discharged to open land or into water ways, polluting them to a very high extent.

Copper is present abundantly in the environment and is an essential micronutrient for the normal growth and metabolism of all living organisms. The United States is the major world producer and consumer of copper and its compounds. Copper release to the global biosphere may approach 1.8 million metric tons per year mostly from anthropogenic activities. Inputs of copper into aquatic ecosystems have increased sharply during the past century due to a number of reasons including atmospheric fallout from industrial activities, waste and industrial discharges, and of antifouling marine paints and wood preservatives. Copper is among the most toxic of the heavy metals in freshwater and marine biota. In the present study, it varied between 1.04 and 1.34mg/L. The WHO limit is 0.05mg/L. Excess copper can cause cellular damage by generating oxygen free radicals and inactivating biological thiols into disulfides [12]. Copper is one of the several heavy metals that are essential to life despite being as inherently toxic as non-essential heavy metals exemplified by lead and mercury [13]. Plants and animals rapidly accumulate it. It is toxic at very low concentration in water and is known to cause brain damage in mammals [14]. Copper is necessary for carbohydrate and nitrogen metabolism. It is also required for lignin synthesis; it is needed for cell wall strength and prevention of wilting. Copper inhibits several enzymes and in excess may cause iron deficiency and its toxicity effect is largely on the root growth and morphology.

Iron is the fourth most abundant, by weight, of the elements that make up the earth's crust. Common in many rocks, it is an important component of many soils, especially clay soils where it is usually a major constituent. Iron is involved in the production of chlorophyll. It is also a component of many enzymes associated with energy transfer. It was established that the iron content ranged from 0.23 to 1.75mg/L in the present study, whereas the critical level of iron in water is 0.1mg/L and the WHO limit is 0.3mg/L. The ferrous, or bivalent (Fe^{++}), and the ferric, or trivalent (Fe^{+++}) ions, are the primary forms of concern in the aquatic environment, although other forms may be in organic and inorganic wastewater streams. At certain concentrations, iron can also be toxic to aquatic life. Iron is essential to most life forms and to normal human physiology. It is an integral part of many proteins and enzymes that maintain good health [15]. In humans, iron is an essential component of proteins involved in oxygen transport [16]. It is also essential for the regulation of cell growth and differentiation [17]. A deficiency of iron limits oxygen delivery to cells, resulting in fatigue, poor work performance and decreased immunity [15, 18]. However, excess amounts of iron in man can result in toxicity and even death [19]. Ingestion of iron accounts for most of the toxic effects because it is absorbed rapidly in the gastrointestinal tract. The corrosive nature of iron seems to further increase the absorption.

Lead is a highly toxic metal substance and it ranged from 0.013 to 0.035mg/L in the present study. The WHO limit is 0.05mg/L. Exposure to lead can produce a wide range of adverse health effects. Both adults and children can suffer from the effects of lead poisoning. Lead accounts for most cases of paediatric heavy metal poisoning [20]. It is a very soft metal and is used in pipes, drains, and soldering materials for many years. Millions of homes still contain lead in painted surfaces, leading to chronic exposure from weathering, flaking, chalking, and dust. Every year, industries produce about 2.5 million tons of lead throughout the world, most of which used for batteries. Lead inputs in the atmosphere from industrial and vehicular exhaust are much greater than natural inputs. Some metals that have received more attention are mercury, cadmium and lead because of their highly toxic properties and effects on the environment and living organisms [21].

Zinc is one of the most ubiquitous and mobile among the heavy metals and is transported in natural waters in both dissolved forms and is associated with suspended particles [22]. Zinc is an essential component of various enzyme systems for energy production, protein synthesis and growth regulations. Its value in the present study area ranged from 0.125 to 1.6mg/L. The WHO limit is 5.0mg/L. In river water, zinc is predominantly present in the dissolved form. Zinc in aquatic environment predominantly binds to suspended material before settling in sediments [23]. These sediments act as the most important reservoir or sink of zinc and other pollutants in the aquatic environment [24]. Heavy metal contamination in sediment can affect the water quality and bioaccumulation of metals in aquatic organisms, resulting in a potential for long term implications on human health and ecosystem [25].

Bioaccumulation of heavy metals like mercury, cadmium, lead, zinc and copper bind with biologically active constituents of the body, *viz*., lipids, amino acids, enzymes and proteins [26]. Christensen and Frandt [27] observed that any biochemical change was dependent on dose response relationship, threshold limit value, and reversible and irreversible effect of toxicants. Heavy metal ions exhibit affinities towards functional group of proteins, sulphahydril amino and carboxyl which in turn disturbs the fundamental physiological and biochemical mechanism in living systems. Heavy metals pollution affects not only aquatic organisms, but also public health as a result of bioaccumulation in food chain. Therefore, contamination of freshwater with heavy metals causes devastating effect on ecological balance of the aquatic environment and on the other hand the diversity of aquatic organisms becomes limited with the extent of pollution.

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