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Heavy Metal Contamination in Bore Water due to Industrial Pollution and Polluted and Non Polluted Sea Water Intrusion in Thoothukudi and Tirunelveli of South Tamil Nadu, India

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Abstract This study investigates the pollution vulnerability of bore water in the coastal region of Tirunelveli and Thoothukudi in the state of Tamilnadu, India. There are no industries in the Tirunelveli Coastal area whereas there are many industries in SIPCOT (State Industries Promotion Corporation of Tamilnadu) Thoothukudi, and coastal area of Thoothukudi. Bore water from the SIPCOT, coastal area of Thoothukudi and Tirunelveli were collected periodically from July 2006 to May 2008 for this study. These samples were tested and analyzed to find the concentrations of sodium, magnesium, aluminium, potassium, calcium, copper, cadmium, mercury and lead. The toxic cadmium concentration was found in the range of 0.00–0.22 mg Kg^{-1} at SIPCOT 2 in November 2007, mercury 0.00–0.024 mg Kg^{-1} and lead 0.00–0.02 mg Kg^{-1} in SIPCOT 2 in January 2008. The level of contamination is higher than the WHO limits of drinking water standards; but copper and aluminium content are within the limit. On the other hand, the samples taken from bores in Tirunelveli coastal area are non-polluted, and the analysis shows that all the metals are within the limits of WHO standard.

Keywords Bore water · Industrial pollution · Seawater intrusion · Heavy metals

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Water is the vital resource, necessary for all aspects of human and ecosystem survival and health. Depending on the quality, bore water may be used for human consumption, irrigation purposes and livestock watering. The quality of bore water can vary widely depending on the quality of ground water that is its source. Pollutants are being added to the ground water system through human and natural processes. Solid waste from industrial units is being dumped near the factories, which react with percolating rainwater and reaches the ground water level. The percolating water picks up a large number of heavy metals and reaches the aquifer system and contaminates the ground water. The usage of the contaminated bore water causes the diseases.

A lot of studies are abounding in the literature on heavy metal contamination of water sources (Poonam et al. 2000). Such works include, evaluation of water quality pollution indices for heavy metal contamination monitoring, (Edet and offiong 2002), physicochemical quality of an urban municipal waste water effluent and its impact on the receiving environment (Emmanuel and Anthony 2009), heavy metal pollution in reef corals of Tuticorin coast, southeast coast of India (Jayaraju et al. 2009). All these workers concluded that there is a need to monitor water quality on a regular basis. The increase in concentration of trace metals in potable water will increase the threat to human health and life. The present study area is currently exposed to a larger degree of metal contamination from the direct discharge of effluents from industries and intrusion of polluted and non polluted seawater. The present study comprises the evaluation of toxic metals present in the bore water of

a. industrially polluted area, SIPCOT Thoothukudi (Table 1). This industrial complex is situated 8 km away from Gulf of Mannar. There are 67 industries are situated in this complex.
b. polluted seawater intrusion Thoothukudi coastal area, (Table 1). This industrial town is located between lattitude 8°15′ to 9°0′ N and longitudes 77°50′ to 78°15′ E in Gulf of Mannar.
c. non-polluted seawater intrusion area, Tirunelveli district coastal area (Table 1). Tirunelveli district lies between 8°05′ and 9°30′ of the northern latitude and 77°05′ and 78°25′ of eastern longitude.

Table 1 Sampling points in various locations

Types of area	Locations
Industrial polluted area SIPCOT	SIPCOT 1
	SIPCOT 2
Polluted seawater intrusion Thoothukudi coastal area	Kamarajar College
	Paniammai Velankanni Church
Non- polluted seawater intrusion Tirunelveli coastal area	Karaisuthu Uvari
	Athankarai palli

Materials and Methods

The samples were collected monthly during the study period of July 2006 to May 2008 in all the above sites. The sample containers were cleaned by 1.0 mol Kg^{-1} of nitric acid and left for 2 days followed by rinsing with distilled water. The samples were collected in clean polythene bottles without any air bubbles. The bottles were rinsed before sampling and tightly sealed after collection and labeled in the field. The temperature of the samples was measured in the field itself at the time of sample collection. The samples were kept in refrigerator maintained at 4°C. Sodium, magnesium, aluminium, potassium, calcium, copper, cadmium, mercury and lead were analyzed by

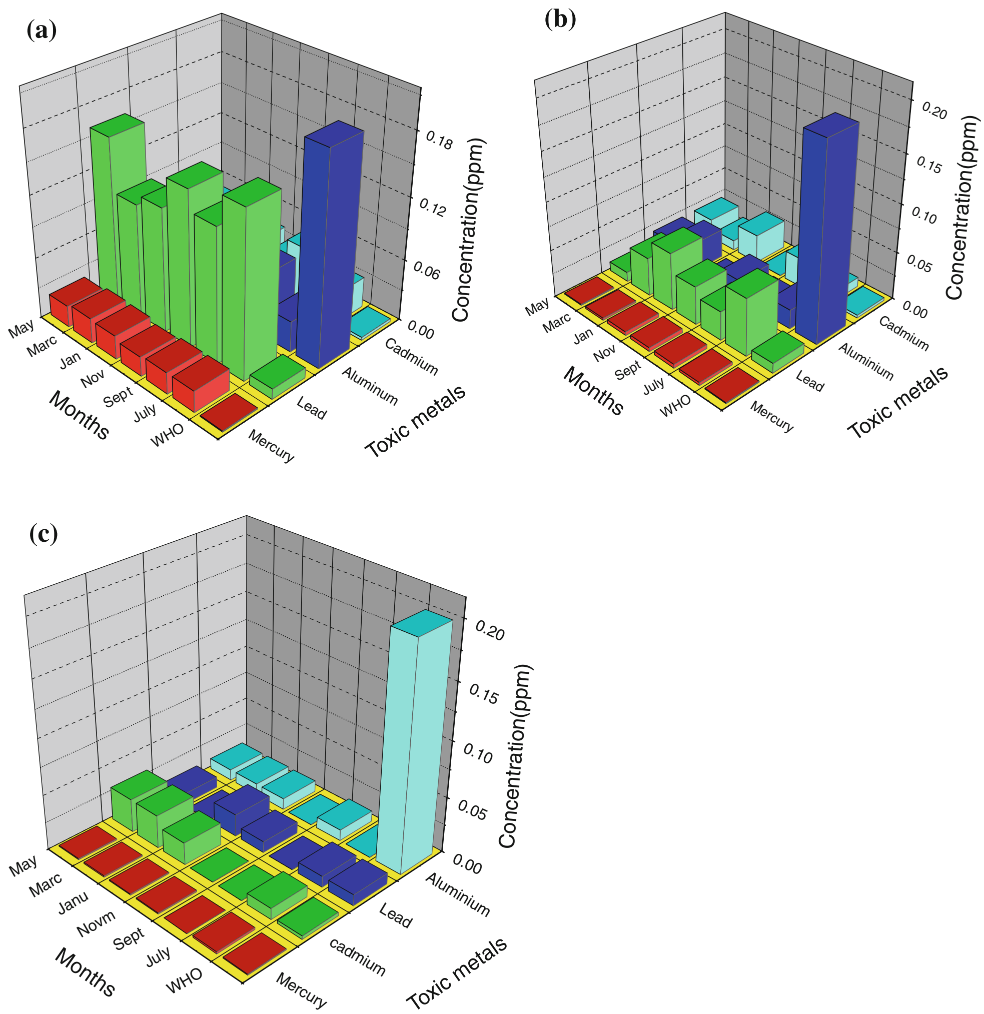

Fig. 1 Toxic metal contamination during July 2006 to July 2007 at **a** in and around SIPCOT **b** Thoothukudi coastal **c** Tirunelveli coastal

Atomic Absorption spectrometry (Model: VARIAN 240 FS). The above analysis was carried out as per standard methods of water and wastewater (APHA 2005). Metal contents were expressed in mg Kg^{-1}.

Results and Discussion

Variation of metal contents in the collected bore water from the studied locations during July 2006 to June 2007 is shown in Fig. 1 and during July 2007 to May 2008 is shown in Table 2. Limits for drinking water standard as per WHO; Hg: 0.001 mg Kg^{-1}; Cd: 0.003 mg Kg^{-1}; Al: 0.2 mg Kg^{-1}; Pb: 0.01 mg Kg^{-1}.

The analytical data showed that mercury concentration varied from below detection limit (BDL = 0.001 mg Kg^{-1}) to 0.026 mg Kg^{-1}. The high concentration of mercury was observed in SIPCOT 1 and SIPCOT 2 during July 2007 and March 2008 due to the discharge of untreated effluent directly to the ground from industries like marine food processing industries. In Thoothukudi coastal and Tirunelveli coastal sites, the concentration of mercury was detected in below detection limit during July 2006 to May 2008. Mercury contamination can cause severe neurological and kidney damage. Acute exposure can affect the respiratory and gastrointestinal systems. Organic mercury can cross the blood–brain barrier and cause irreversible nervous system and brain damage (Poonam et al. 2000).

The concentration of lead in the collected water samples varied from BDL, 0.01 mg Kg^{-1} to 0.21 mg Kg^{-1}. Low level concentration of lead was observed in the bore water samples of Tirunelveli and Thoothukudi coastal areas. SIPCOT 1 registered high level of lead during November 2007 and March 2008 while the lead level at SIPCOT 2 was high during January 2008 and November 2007. The untreated industrial wastewater containing lead readily forms complexes with humic substances. These organic materials will affect the solubility of lead in these wastewaters. At such levels, lead toxicity problems are to be expected from these waters. Higher concentration of lead has adverse effect on central nervous system, blood cells and may cause brain damage (Lars 2003). The discharge of untreated effluent containing lead from oil processing units, steel metal units and petrol bunk industries is one of the reasons for high level of lead present in bore water. Table 2.

Table 2 The concentration of toxic metals in the bore water collected during July 2007 to May 2008

Locations	Concentration (mg Kg^{-1})	July 07	Sep 07	Nov 07	Jan 08	Mar 08	May 08
Tirunelveli coastal location 1	Hg	0.001	0.00	0.002	0.001	0.002	0.002
	Cd	0.00	0.01	0.01	0.04	0.03	0.01
	Al	0.01	0.01	0.01	0.00	0.01	0.00
	Pb	0.01	0.00	0.02	0.00	0.02	0.01
Tirunelveli coastal location 2	Hg	0.00	0.002	0.001	0.00	0.001	0.00
	Cd	0.01	0.01	0.00	0.01	0.02	0.00
	Al	0.01	0.01	0.01	0.01	0.00	0.01
	Pb	0.01	0.00	0.00	0.02	0.01	0.02
Thoothukudi coastal location 3	Hg	0.001	0.003	0.001	0.003	0.001	0.005
	Cd	0.03	0.01	0.01	0.01	0.01	0.01
	Al	0.01	0.02	0.00	0.02	0.02	0.03
	Pb	0.06	0.04	0.07	0.06	0.08	0.03
Thoothukudi coastal location 4	Hg	0.005	0.003	0.002	0.004	0.005	0.005
	Cd	0.00	0.01	0.02	0.02	0.00	0.02
	Al	0.02	0.03	0.00	0.01	0.01	0.04
	Pb	0.07	0.08	0.07	0.03	0.05	0.06
SIPCOT1 location 5	Hg	0.023	0.018	0.022	0.021	0.023	0.020
	Cd	0.20	0.20	0.18	0.21	0.20	0.20
	Al	0.04	0.02	0.04	0.04	0.06	0.04
	Pb	0.16	0.15	0.18	0.13	0.18	0.15
SIPCOT2 location 6	Hg	0.020	0.023	0.019	0.024	0.022	0.020
	Cd	0.20	0.19	0.22	0.19	0.21	0.20
	Al	0.06	0.09	0.09	0.08	0.05	0.08
	Pb	0.13	0.15	0.19	0.20	0.18	0.18

The concentration of cadmium in collected bore waters varied from 0.01 mg Kg^{-1} to 0.23 mg Kg^{-1}. Low level of cadmium was observed in Thoothukudi and Tirunelveli coastal area. The high concentration of cadmium (0.22 mg Kg^{-1}) was observed in SIPCOT 1 and SIPCOT 2. The discharge of untreated effluent containing cadmium from mining and smelting, electroplating, pigment and plasticizer production industries in SIPCOT is responsible for increased level of cadmium in the bore water. It is accumulated in kidney of human beings. It interferes with certain enzymes and causes hypertension, liver and lung cancer. Recent data indicates that adverse health effects of cadmium exposure may occur at lower levels than previously anticipated, primarily in the form of kidney damage but possibly also bone effects and fractures (Lars 2003). Therefore, measures should be taken to reduce cadmium exposure in the general population in order to minimize the risk of adverse health effects. The concentration of aluminium was varied from 0.01 to 0.10 mg Kg^{-1}. All the analysed samples indicate that the level of aluminium and copper in the bore water is within the limit.

It was observed that in most of the samples, magnesium exceeded the drinking water standard as per WHO permissible limit. Due to the intrusion of polluted seawater, Thoothukudi sampling sites got the higher concentration of magnesium than Tirunelveli region. In SIPCOT sites, the concentration of magnesium is higher than the other two sampling regions due to the intrusion of polluted seawater and direct discharge of industrial wastewater. Magnesium rich water may cause the gastrointestinal irritation in the presence of sulphate and act as laxative to human beings (Buddhi et al. 2002).

The high level of sodium and potassium was observed in SIPCOT industrial area and Thoothukudi coastal region compared to the Tirunelveli region. Intake of high level of sodium causes increased blood pressure, arteriosclerosis, oedema and hyperosmolarity. High water soluble potassium causes damage to germinating seedling, inhibits the uptake of other minerals and reduces the quality of the crop. Low concentration of calcium was observed in Tirunelveli and Thoothukudi coastal and high level in SIPCOT 1 and 2. The concentration of calcium exceeds the limit of 100 mg Kg^{-1} prescribed by WHO as standard. These chemical pollutants affect human health directly or indirectly by accumulations in the aquatic animals used as human food in the coastal areas as fish is the main source of food.

Most of the bore water samples in Tirunelveli, Thoothukudi coastal areas are not suitable for drinking purpose though the metal contamination is low. In the industrial belt of SIPCOT, the bore water gets more polluted than other sampling sites due to the direct discharge of industrial untreated wastewater and intrusion of polluted seawater. The analysis showed that the concentrations of metals and other parameters exceeded the permissible limit as per drinking water specification of WHO. Hence, it is recommended that suitable water quality management is essential to avoid any further contamination.

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