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Trace Element Concentration in Groundwater, Tuticorin City, Tamil Nadu, India

S. Krishna Kumar · N. S. Magesh · N. Chandrasekar

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Abstract The aim of the present study is to investigate the pollution vulnerability of groundwater aquifers in the coastal regions of Tuticorin city, Tamil Nadu, India. Fourteen samples were analyzed to determine the concentration of trace elements (Pb, Zn, Cd, Hg, Cr and Cu) in the groundwater. Among the total samples six were collected from industrial areas and eight from non-industrial areas of Tuticorin city. The concentration of trace element ranges from 0.01 to 0.19 mg/kg^{-1} for Pb, from 0.01 to 0.16 mg/kg^{-1} for Zn, from BDL to 0.21 mg/kg^{-1} for Cd, from BDL (Below Detection Limit) to 0.023 mg/kg^{-1} for Hg, from 0.02 to 0.18 mg/kg^{-1} for Cr and from 0.01 to 0.16 mg/kg^{-1} for Cu. The trace element concentration in groundwater is higher than the WHO suggested maximum permissible limit except Zn and Cu.

Keywords Trace elements · Groundwater · Pollution vulnerability · Tuticorin city

Trace elements are contributed to groundwater from a variety of natural and anthropogenic sources (Abollino et al. 2004; Leung and Jiao 2006). Some of the trace elements like Fe, Mn, Ni, Cu, Zn, and As are essential for the human body to activate vital functions and biological processes. But the trace element beyond the permissible limit can cause several health hazards (WHO 1984). Tuticorin lies between 8°39′ and 8°51′N latitude and 78°57′ and 78°12′E longitude in the state of Tamil Nadu, India (Fig. 1). The study area spreads a geographical area of 358 km^2. This area has a subtropical climate with medium evaporation ($\sim$200 cm $year^{-1}$). During the past three decades there has been a dramatic surge in industrial development on the coast due to the establishment of a number of large scale industries including thermal power plant, fertilizer, chemical and mineral processing plants, textile mills, match factories and nearly 500 small scale industries. A large number of researchers have also worked on trace element contents of groundwater in Indian subcontinent and along its coastal area (Ramesh et al. 1995; Das 2003; Mandal and Sengupta 2006; Puthiyasekar et al. 2010; Krishna Kumar et al. 2011). This paper provides comparative data (industrial and non-industrial) on metal contamination resulting from the activities of heavy industries situated around city.

Materials and Methods

Groundwater samples were collected from fourteen representative wells in industrial and non-industrial areas of coastal tracts of Tuticorin city. The water samples were collected in pre-cleaned (with 1 N HCl) Polyethylene bottles which are filtered, acidified with nitric acid (1 N) and stored at 10°C for further laboratory analysis. The trace element analysis (Pb, Zn, Cd, Hg, Cr and Cu) were performed by IRIS INTREPID II XSP-Thermo Electron Corporation model with Induced Coupled Plasma Atomic Emission Spectrophotometer. The detection limits of trace elements were 0.01 mg/kg^{-1} for Cu, Cr, Zn, Cd, 0.001 mg/

Present Address:
S. Krishna Kumar · N. S. Magesh · N. Chandrasekar
Centre for GeoTechnology, Manonmaniam Sundaranar University, Tirunelveli 627 012, Tamil Nadu, India
e-mail: mageshissivan@gmail.com

N. Chandrasekar
e-mail: profncsekar@gmail.com

S. Krishna Kumar (✉)
Department of Civil Engineering, St.Peters University, Avadi, Chennai 600 055, Tamil Nadu, India
e-mail: coralkrishna@yahoo.co.in

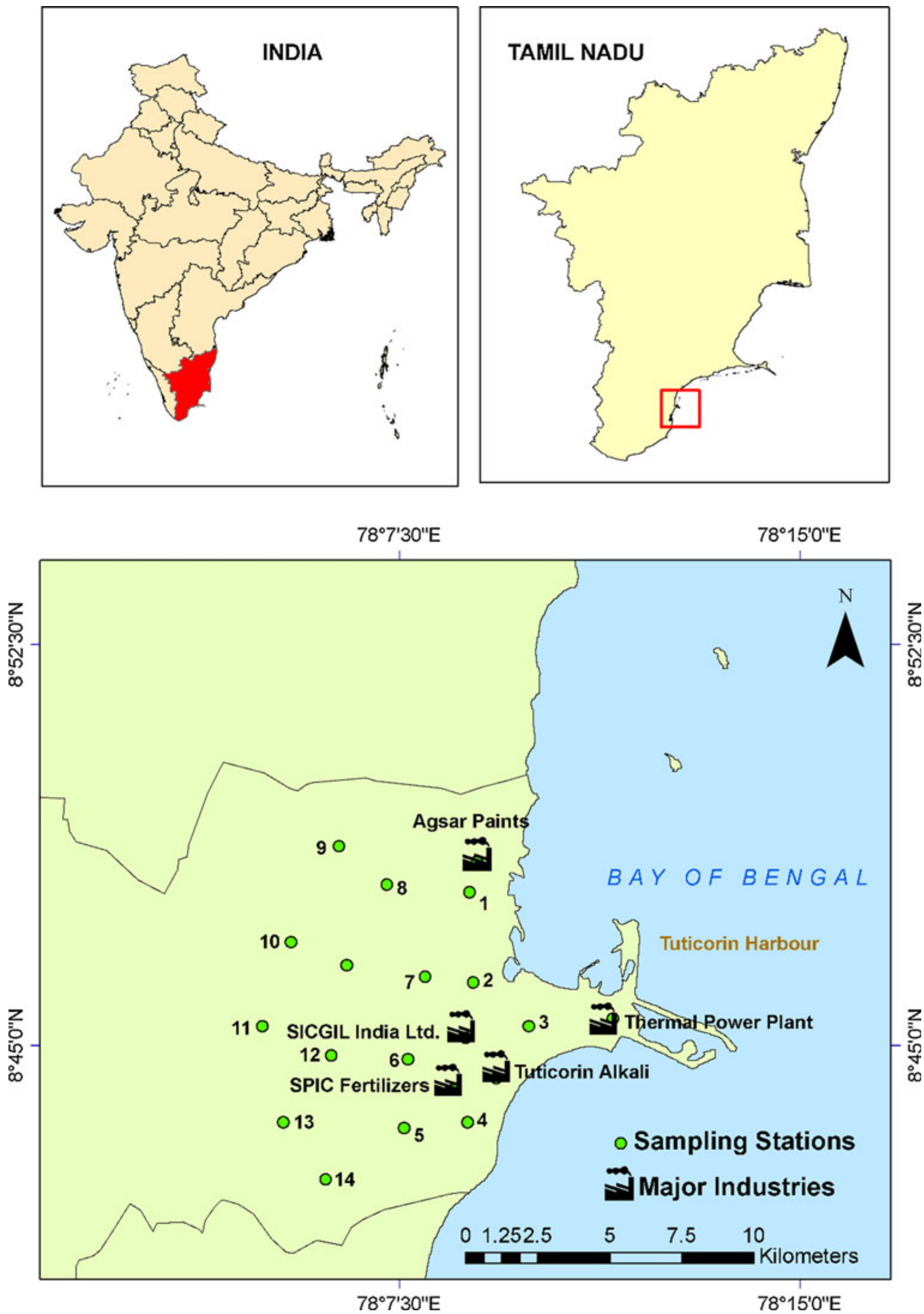

Fig. 1 Location map of the study area and sampling points of groundwater

kg^{-1} for Hg and 0.05 mg/kg^{-1} for Pb. The analytical procedures are as suggested by American Public Health Association (APHA 1995).

Results and Discussion

The concentration of trace elements in groundwater is helpful to monitor the terrestrial anthropogenic pollutions. The concentration of Pb ranges from 0.01 to 0.19 mg/kg^{-1} with an average value of 0.071 mg/kg^{-1}. In few locations, the concentration of Pb in groundwater samples is higher than the WHO standards. The lead containing untreated industrial waste water can rapidly forms complexes with humic substances and it will affect the solubility of lead in waste waters. Higher concentration of lead has adverse effect on central nervous system, blood cells and may cause brain damage (Lars 2003). The lead contamination is probably from petrochemical industries and metal smelting units. The concentration of Zn ranges from 0.01 to

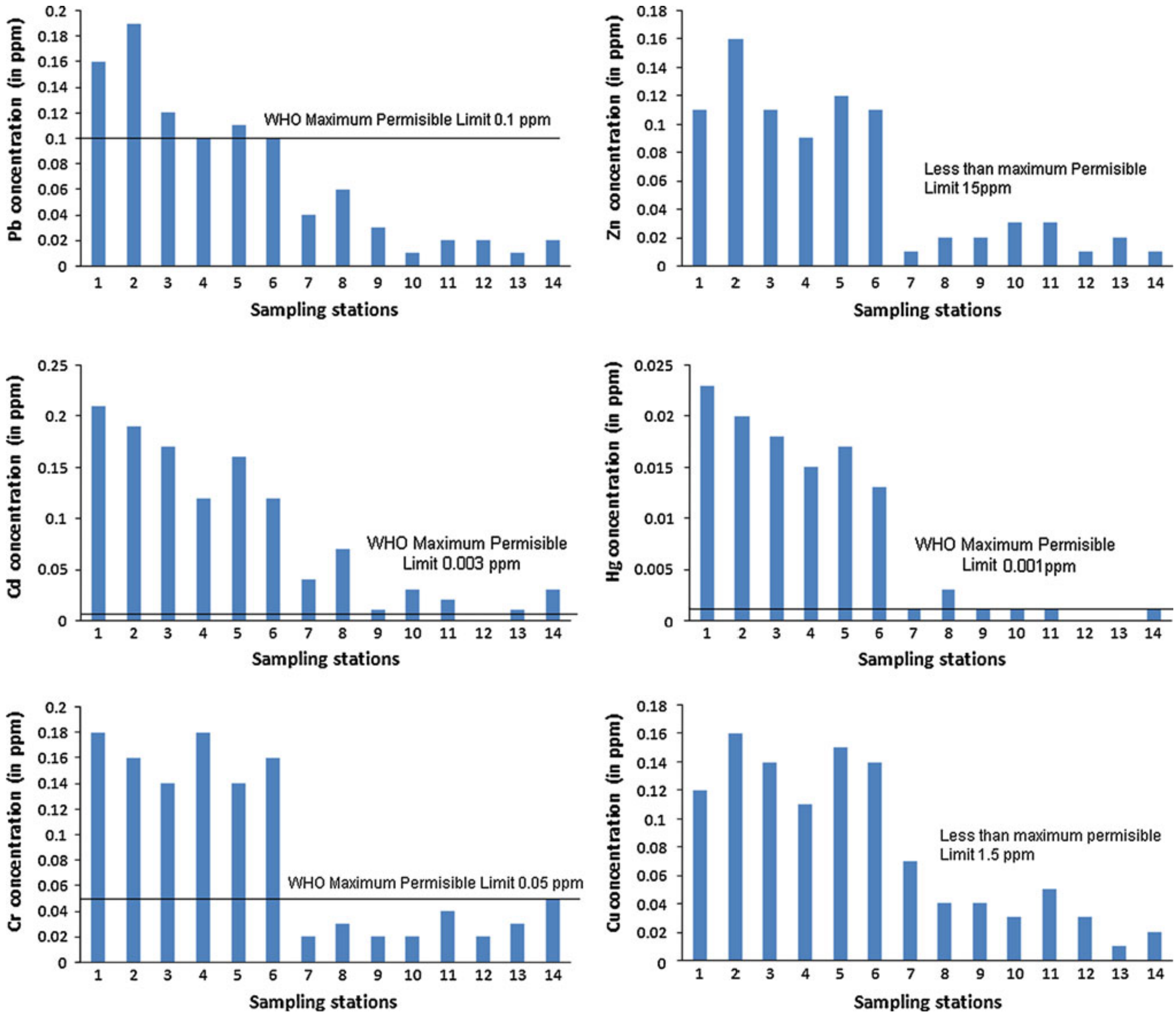

Fig. 2 Trace element concentration compared with WHO standard (1984)

0.16 mg/kg^{-1} with an average of 0.061 mg/kg^{-1}. The concentration of Cu and Zn are very low compared to WHO standard in all the sampling locations. The concentration of Cd ranges from BDL (Below Detection Limit) to 0.21 mg/kg^{-1}. The severe contamination of Cd gives raise to itai–itai disease (Yosumura et al. 1980). The Cd concentration is higher than the WHO maximum permissible limit of 0.003 mg/kg^{-1} in all the samples. The cadmium content is possibly derived from smelting, electroplating and pigment industries. The concentration of Hg ranges from BDL to 0.023 mg/kg^{-1} with an average being 0.010 mg/kg^{-1}. Mercury contamination can cause severe neurological, kidney and brain damages. The Cr and Cu concentration ranges from 0.02 to 0.18 mg/kg^{-1} and 0.01 to 0.16 mg/kg^{-1} with an average concentration of 0.085 and 0.079 mg/kg^{-1} respectively. The Cr concentration is higher than the WHO suggested maximum permissible limit in industrial areas. The trace element concentration compared with World Health Organization (WHO) standard (1984; Fig. 2). The trace element concentration is higher in industrial areas when compared to other sample locations of Tuticorin city.

Statistical analysis was carried out using SPSS software package for the metal concentration to detect the difference between the ground water samples. The correlation matrix of metal ions was presented in Table 1. Pb, Zn, Cd, Hg, Cr and Cu shows good positive factor loading in factor1, Zn, Cr and Cu have positive factor loading in factor 2 and Hg and Cr have positive factor loading in factor 3 (Fig. 3). The extracted factor loading clearly suggest that the trace element concentration is most probably contributed from anthropogenic sources.

Table 1 Correlation coefficient matrix (r^2) of trace elements in groundwater

Parameters	Pb	Zn	Cd	Hg	Cr	Cu
Pb	1.000					
Zn	0.936	1.000				
Cd	0.966	0.931	1.000			
Hg	0.958	0.95	0.985	1.000		
Cr	0.889	0.922	0.913	0.955	1.000	
Cu	0.909	0.95	0.912	0.921	0.892	1.000

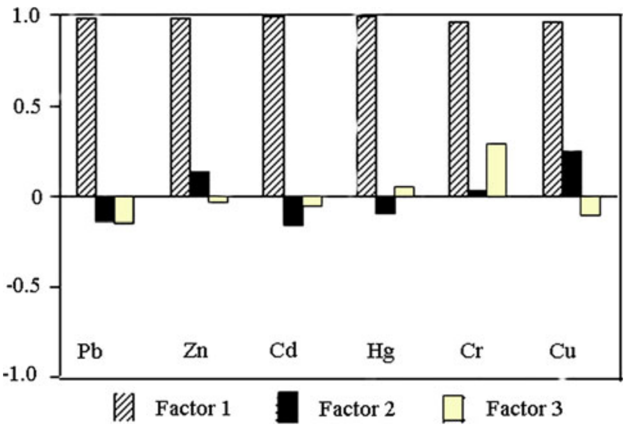

Fig. 3 Factor analysis results of trace elements in groundwater

The anthropogenic activities have took place in that area over the last five decades which cause damaging effect on the groundwater aquifers due to the large quantities of industrial and domestic sewage water discharge. Hence the study area is getting polluted by trace elements. If the level of trace elements continues to increase then the toxic effect will also be increased. The proper installation of sewage treatment plant, draining of treated industrial effluence and creation of public awareness about the trace element pollutants are the solutions to protect the groundwater aquifers.

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