CONTAMINANT OF HEAVY METALS IN GROUNDWATER AND ITS TOXIC EFFECTS ON HUMAN HEALTH : A STUDY FROM KARUR BLOCK AREA, TAMIL NADU

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Abstract

The ground water is the important water resource for the developing nations including rural India. The increase in population, modernization, and alternate water supply schemes, the ground water getting polluted mainly due to the discharge of wastewater from residential areas, sewage outlets, solid waste dump sites, livestock rearing sites (e.g., dairy, poultry), and fertilizers and pesticides from farmers' fields. The sludge accumulated in these water bodies may contain an appreciable amount of toxic metals that may leach to the groundwater and long-term use of contaminated water, either directly from these water bodies or the nearby handpumps or tubewells, can cause serious threats to human health. The water is drinking of highly polluted and chronic effect on people are genetic disorders, nerutoxicological disorder and carcinogenicity. This study investigated nine heavy metal (Fe, Pb, Cd, Zn, Cu, Ni, Cr, Co and Mn) contamination in the groundwater at ten stations in Karur block area, Tamil Nadu (India), and provides a sound case for examining the toxic metal accumulation in the water bodies.

Keywords: ground water, heavy metals, correlation matrix, toxicity

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Introduction

Ground water is found in well water and bore well [1,2]. The environmental contaminations by the toxic substances are growing that cause major concern to the local users. An extensive area of pollutants is constantly introduced into the aquatic environment primarily due to amplified industrial activity, technical development, growing human population and mistreatment of natural resources, agriculture and domestic wastes run-off. These pollutants, heavy metals found one of the most hazardous since of their stubborn nature, tendency, toxicity to accrue in organisms and undergo food chain increase and more still, they are non-degradable. Heavy metal causing major toxicity in humans like damage cardiovascular gastrointestinal track and CNS, the, endocrine glands, kidneys, liver, lungs, and bones. It is not probable to fully avoid contact to toxic metals. It is, though, probable to decrease metal toxicity risk concluded lifestyle se lections that contract the possibility of injurious heavy metal approval, such as alimentary procedures that may promote the safe metabolism or excretion of ingested heavy metals [3]. Humans have evolved in the presence of metals and are adapted to various levels of essential and non-essential metals. Excess metals in body are excreted through urine and faeces or accumulated in various tissues. At higher concentrations metals become toxic. The supreme significant environmental problems today are ground water pollution [4] and among the extensive variety of pollutants effecting water properties, heavy metals obtain specific concern seeing their tough toxicity even at small applications [5]. Heavy metal can origin major effects of health with diverse signs dependent on the nature and amount of the heavy metal consumed [6]. Domestic uses of groundwater are used for agriculture and industrial determination in many parts of the world. Human Activities like swage and waste water release huge number of pollutants into the water. In India surface water and ground water are used for the anthropogenic and agriculture and industrial purpose [7]. In now days the growing of many industrial development machinery, incising pollutions and water are used to improvement of the pressure upon together our water and land sources. Contamination difficulties contain sewerage leakage procedure and landfills leeching. Some seaside areas, thorough impelling of fresh bore well water has produced salt water to interrupt into fresh-water aquifers. The growth process of world contamination of water are biggest threats have become progressively apparent and have led to major environmental problems [8]. Heavy metals such as iron (Fe), cobalt (Co), chromium (Cr), magnesium (Mn), and zinc (Zn) are considered non-carcinogenic at lower concentrations and acts as micronutrient, while at higher concentration they may have some health hazards [9]. Heavy metals such as cadmium (Cd), lead (Pb), and arsenic (As), are highly toxic to humans and other organisms [10,11]. The assessment of these heavy metals in pond sludge/soil, water, and nearby groundwater is necessary to assess human, ecological, and soil health risks. In this study, groundwater samples are being collected during post-monsoon and pre-monsoon seasons (January 2023 and June 2023). They were analyzed for their heavy metals, such as Fe, Pb, Cd, Zn, Cu, Ni, Cr, Co and Mn. Their concentrations during pre- and post-monsoon seasons were compared. Using BIS (2012) the quality of groundwater at some locations is being warranted.

MATERIALS AND METHODS

Sampling: Ten groundwater samples were collected from bore and hand pumps during January (2023) and June (2023), representing the post-monsoon and pre-monsoon seasons, respectively. In addition to a variety of land-use patterns, bore wells and hand pumps for sampling were chosen on the basis of an industrial unit. The GIS map of the study region is shown in Fig.1 along with the locations of the sampling. Water collection stations in Karur area shown in Table 1. High-density white polyethylene bottles were utilized to collect the samples. Laboratory testing was done on the labelled water samples to determine their physico-chemical characteristics. The American Public Health Association (APHA 2005) recommended practices were adhered to when collecting samples for handling and preservation in order to ensure the validity and dependability of the results.

Analytical procedures: The total dissolved solids (TDS), hydrogen ion concentration (pH), and electrical conductivity (EC) were determined immediately on location using water quality multitester probe (Eutech PC Tester 35). The concentrations of trace elements were quantitatively determined by atomic absorption spectroscopy (AAS).

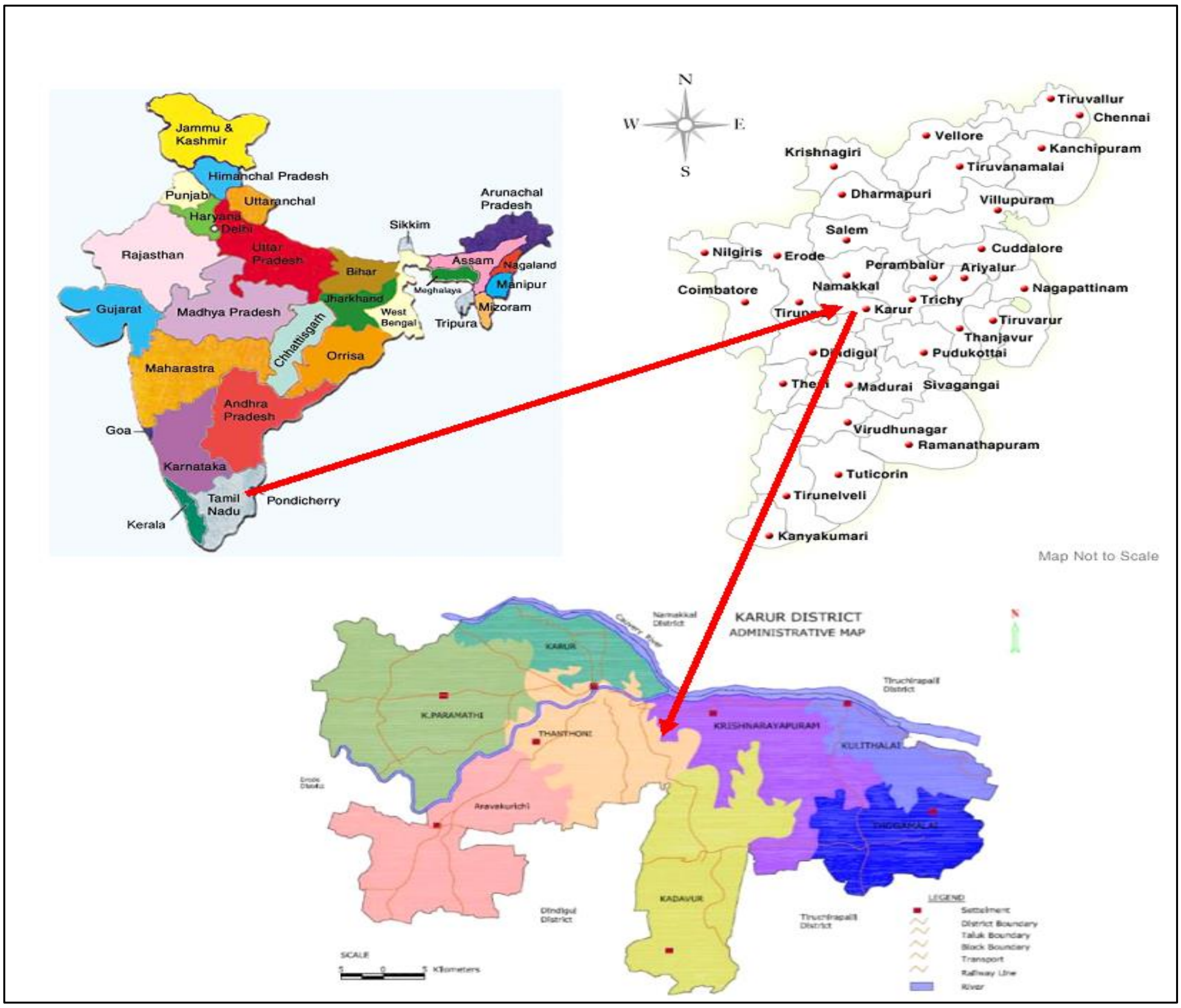

Fig.1: Sampling location

Table 1: Water collection stations in Karur

Station No.	Place	Location
S1	**Nanniyur**	11.0552 Latitude and 78.0095 Longitude
S2	**Thalappatti**	10.957348 Latitude and 78.080927 Longitude
S3	**Emur**	10.9227966 Latitude and 78.1165269 Longitude
S4	**Thaanthoni malai**	10.9301249 Latitude and 78.0908511 Longitude
S5	**Puliyur**	10.936682 Latitude and 78.1521606 Longitude
S6	**Melappalayam**	10.9293 Latitude and 78.15385 Longitude
S7	**Vaangal**	11.129655 Latitude and 78.1478812 Longitude
S8	**Manavadi**	10.8882855 Latitude and 78.1029778 Longitude
S9	**Aathum**	10.9338334 Latitude and 78.0883645 Longitude
S10	**Somur**	10.9879951 Latitude and 78.1260397 Longitude

Results and Discussion

Groundwater chemistry and spatial distribution

The pH value indicates that the samples are faintly alkaline in nature (>7), due to the collective effect of the high concentration of dissolved ions, variation in soil types, various aquifer systems, and anthropogenic activities, especially agricultural activities in the study area. The pH value of groundwater is mainly controlled by the amount of dissolved carbon dioxide, carbonate, and bicarbonate concentration [12]. The maximum TDS value of groundwater samples in the study area ranged 898 and 982 mg/L (both seasons), which may due to saline water intrusion and nutrient enrichment due to fertilizers could enhance TDS and, in turn, increases the EC in the lower basin.

Table 1 : Minimum and maximum concentration of each parameter with its BIS limit

Parameter	Post-monsoon	January 2023	Pre-monsoon	June 2023	BIS limit (2012)	
	Minimum	Maximum	Minimum	Maximum	Acceptable	Permissible
pH	7.18	7.92	7.24	8.1	6.5–8.5	No relaxation
TDS mg/l	390	898	428	982	500	2000
EC µS/cm	610	878	688	920	–	–
Fe mg/L	0.002	0.523	0.012	0.628	0.3	No relaxation
Pb mg/L	0.214	0.456	0.089	0.802	0.01	No relaxation
Cr mg/L	0.180	0.718	0.560	0.956	0.05	No relaxation
Zn mg/L	0.120	0.170	0.340	0.672	5	15
Cu mg/L	0.05	0.158	0.042	0.178	0.05	1.5
Ni mg/L	0.066	0.780	0.033	0.630	0.02	No relaxation
Co mg/L	0.085	0.565	0.273	0.83	–	–
Mn mg/L	0.020	0.180	0.030	0.172	0.1	0.3

In the study area, Fe ranges from 0.002 to 0.523 mg/l in pre-monsoon season and 0.012–0.628 mg/l in post-monsoon. During both seasons, in most of the samples, it is below the acceptable limit except the sample taken from Thalappatti, Thaanthoni malai, Puliyur and Aathum which shows values above the acceptable limit. The result of increasing value of iron during pre-monsoon is due to rock–water interaction [13]. At some places, concentration of iron in groundwater is due to corrosion of household and leaching from pipes, fitting, smelting, and welding work places [14,15,16]. Acceptable limit for lead is 0.01 mg/l (BIS 2012) [17] . For the study area, lead concentration varies from 0.089 to 0.802 mg/l ; and during POM, it varies from 0.214 to 0.456 mg/l. Concentration of Pb in groundwater of the study area increases in both season due to the influence of rain during monsoon that takes the Pb along with petrol fuel from roadside [18,19]. It is also due to the releaseof lead-containing plumbing material including unplasticized polyvinyl chloride (uPVC) pipes that react with slightalkaline nature of water [20]. Drinking such contaminated water is associated with hip fracture for both genders [21], damage to the kidneys and creates hypertension for humans [18,19].

The concentration of Cr is higher than the acceptable limit in all locations during both seasons. Its minimum and maximum concentrations were 0.180 and 0.718 mg/l during post-monsoon, and 0.560 and 0.956 mg/l during pre-monsoon, respectively. Chromium gives adverse effects when it exceeds its limit [14,15]. Higher concentration of chromium in groundwater of this region is probably derived from dumping sites of municipal wastage, sewage and chrome plating industries by the influence of rainwater being precipitated [22]. Due to rapid urbanization, the dumping of municipal wastes isincreasing day by day in the study area.

Zn is also anessential nutrient to human that is found in most of the natural foods [23] but its required and permissible limit are 5 and 15 mg/l, respectively (BIS 2012). Zinc concentration in all samples, in both seasons,was below the required limit of BIS (2012). Humans need arequired level of Zn, otherwise it affects the metabolism and immune system and as a result human beings are susceptible to infections, delayed sexual maturation in men, and anemia and birth defects in pregnancy women [24]. Concentration of the zinc in groundwateris due to corrosion of household and leaching from piping, fitting, smelting, and welding workplaces [14,15,16].

Concentration of copper in groundwater during pre-monsoon is ranging from 0.042 to 0.172 mg/l and during post-monsoon it is ranging from 0.05 to 0.158 mg/l. Concentration of Cu was within permissible limit in both monsoons and at the same time, most of the samples were not having the required limit for drinking purpose during both monsoons. Even though the values are within permissible limit, the higher concentrations at some places are due to agriculture activity in the area where copper leached from copper-based fertilizer and fungicide is being added to groundwater by rainwater and irrigation water [25,26], and some concentrations are due to leaching from open dumping sites of solid wastes [27], and corrosion of household materials .

In the post-monsoon, the concentration of nickel ranges from 0.066 to 0.718 mg/l, and during the pre-monsoon it ranges from 0.033 to 0.630 mg/l. In station no.10 (Somur) maximum Ni concentration found to be 630 mg/l (post-monsoon) , 718 mg/l (pre-monsoon) respectively. The USEPA (1995) [28] reported that nickel will cause body weight loss, damage of heart and liver, and dermatitis, when consumed long time above the maximum contamination level. Source of nickel in the study area is probably from sewage water and concentration from corrosion of nickel alloy materials [29].

Concentration of cobalt values ranges from 0.085 to 0.565 mg/l during post-monsoon, and ranges from 0.273 to 0.830 mg/l during pre-monsoon. The higher concentration of Co is due to leaching from solid waste sites in the study area [29]. Its continuous consumption above permissible limit adversely affects the heart. There is no guideline value for cobalt in the Bureau of Indian Standards (BIS 2012).

Mn concentration ranges from 0.020 to 0.180 mg/l in pre-monsoon, and during post-monsoon it ranges from 0.030 to 0.172 mg/l. Concentration of Mn in all samples are within permissible limit.

Correlation matrix: The principal component analysis was based on the eigen values in the correlation matrix. The close inspection of correlation matrix was useful because it can point out associations between variables that can show the overall coherence of the data set and indicate the participation of the individual chemical parameters, a fact which commonly occurred in hydrochemistry [30]. A correlation of +1 indicates a perfect positive correlation between two variables. A correlation of - 1 indicates that one variable changes inversely with relation to the other. A correlation of zero indicates that there is no correlation between the two variables [31]. In this study, correlation matrix was done for eight heavy metals and three field parameters. Only those with correlation values higher than 0.5 were considered [32] for both pre-monsoon and post-monsoon seasons, respectively. During the pre-monsoon season, there is no significant correlation between each parameter, but high negative correlation has been observed between EC and Fe; TDS and Ni; Pb and Ni (Table 2). Sources of heavy metals and other parameters are not common to any specific sources. During the post-monsoon season, highly positive correlation is observed between Fe and Cu as well as good correlation of EC with Cr. Correlation between iron and zinc indicates that they might have been derived from the same source such as corrosive activity of iron–copper alloy of household material [14-16] and leachate of discharge in soil from automobile industry in post-monsoon season (Table 3).

Table 2 : Correlation matrix between heavy metals and other parameters during pre-monsoon (June 2023)

Place	pH	EC	TDS	Fe	Pb	Cr	Zn	Cu	Ni	Co	Mn
pH	1										
EC	0.668	1									
TDS	0.959	0.6041	1								
Fe	0.2151	-0.2411	0.2687	1							
Pb	0.1726	0.0479	0.2641	0.3331	1						
Cr	0.6291	0.2861	0.6952	-0.0044	0.596	1					
Zn	0.5897	0.233	0.6407	0.4092	0.1725	0.3903	1				
Cu	0.2454	0.2839	0.2126	0.5383	0.6432	0.1662	0.3789	1			
Ni	-0.4016	0.0663	-0.3369	0.0695	-0.0304	-0.3874	0.0638	0.2078	1		
Co	0.6916	0.6493	0.5897	0.0305	0.53	0.6293	0.0850	0.4505	0.7525	1	
Mn	0.4835	0.5252	0.5209	0.289	0.6342	0.5736	0.3818	0.716	0.6985	0.5986	1

Table 3 : Correlation matrix between heavy metals and other parameters during post-monsoon (January 2023)

Place	pH	EC	TDS	Fe	Pb	Cr	Zn	Cu	Ni	Co	Mn
pH	1										
EC	0.586	1									
TDS	0.8237	0.3594	1								
Fe	0.2295	0.5776	0.1824	1							
Pb	0.5446	0.64	0.4018	0.3632	1						
Cr	0.5611	-0.0169	0.584	-0.2634	0.5549	1					
Zn	-0.1294	-0.0039	-0.0179	-0.0755	0.319	0.1233	1				
Cu	0.2537	0.8088	0.1643	0.8358	0.5885	-0.1623	-0.0354	1			
Ni	0.4245	0.63	0.0737	0.2697	0.7142	0.2487	0.3298	0.4874	1		
Co	0.6517	0.2993	0.5058	0.1228	0.7148	0.7255	0.1173	0.1347	0.6464	1	
Mn	0.4187	0.8584	0.0951	0.5863	0.5951	-0.0752	0.1642	0.7831	0.8262	0.7255	1

In the study area, the assessment of water quality was performed to understand its suitability for drinking and domestic purposes. This study shows that Pb, Cr, Zn, Ni levels in all the groundwater above the permissible limits, its causing toxicity to human. The toxicologist has constantly noticed the heavy metal concentration in several groundwater, plants, herbs, soil, etc. directly affected by human health is the drinking of polluted groundwater. People should be beware of the hazardous effects of drinking polluted water. It is suggested that consciousness must be spread between the people about the toxic on consumption of polluted groundwater and contaminated eatables. It is also important that agriculturalists must be educated to decrease such pollution and should be encouraged to use the controlled quantity of pesticides, to avoid the leaching of waste water. Cultivation of fields should be practiced far away from industrial region as well as areas disposed to pollution. Technologies are suggested for field cultivation and commercialization in the growing countries also where cultivation, urbanization, E-waste and industrialization are leaving a legacy on environmental degradation of heavy metals [33].

Conclusion

This study shows that Pb, Cr, Zn, Ni levels in all the groundwater above the permissible limits, its causing toxicity to human. Groundwater come to be polluted by the major heavy metals through discharges from the quickly increasing industrial regions, discarding of metal wastes, leaded gasoline and paints, etc. A major requirement to conserve controller on discarding of polluted industrial water sources and to anthropogenic pollution of the heavy metal in the groundwater. Water quality testing is necessary for the protection of human health and the environment. The awareness should be extent among the people concerning the toxicity of drinking groundwater contaminated. Moreover, it is recommended that regular monitoring of drinking water should be enforced around the industrial hub as metal accumulation can be toxic to consumers when they are present in excess, and if found elevated appropriate action to reduce exposure should be taken.

References

1. McMurry J, Fay RC (2004) Hydrogen, Oxygen and Water. In: McMurry Fay Chemistry, Hamann KP (Ed.). (4th edn), New Jersey: Pearson Education, pp: 575-599.
2. Mendie U (2005) The Nature of Water. In: The Theory and Practice of Clean Water Production for Domestic and Industrial Use. Lacto-Medals Publishers, Lagos, pp: 1-21.
3. Kumar R, Tripathi RM, Gupta AK (2014) Seasonal Variation of heavy metal concentration in water of River Yamuna, Allahabad, Uttar Pradesh, India. Int J Curr Microbiol App Sci 3(7): 945-949.
4. Vodela JK, Renden, Lenz SD, Mchel Henney WH, Kemppainen BW (2001) Drinking water contaminants. Poult Sci 76: 1474-1492.
5. Marcovecchio JE, Botte SE, Freije RH (2007) Heavy Metals, Major Metals, Trace Elements. In: Nollet LM (Ed.), Handbook of Water Analysis. (2nd edn), CRC Press, London, pp: 275-311.
6. Adepoju-Bello AA, Alabi OM (2005) Heavy metals: A review. The Nig J Pharm 37: 41-45.
7. Kamble PN, Gaikwad VB, Kuchekarl SR (2011) Monitoring of Physico Chemical Parameters and Quality Assessment of Water from Bhandaradara Reservoir. Der Chemica Sinica 2(4): 229-234.
8. Shah DG, Patel PS (2011) Physico-chemical characteristics of bore wells drinking water of Kathalal territory district-Kheda, Gujarat. Der Chemica Sinica 2(5): 8-11.
9. Pal D, Maiti S K (2018) Seasonal variation of heavy metals in water, sediment, and highly consumed cultured fish (Labeo rohita and Labeo bata) and potential health risk assessment in aquaculture pond of the coal city, Dhanbad (India). Environ Sci Pollut Res 25 (13):12464-12480.
10. Malyan SK, Singh R, Rawat M, Kumar M, Pugazhendhi A, Kumar A, Kumar V, Kumar SS (2019) An overview of carcinogenic pollutants in groundwater of India Biocatal Agric Biotechnol 21:Article 101288, 10.1016/j.bcab. 2019.101288
11. Malyan S K, Kumar S S, Fagodiya R K, Ghosh P, Kumar A, Singh R, Singh L (2021) Biochar for environmental sustainability in the energy-water-agroecosystem nexus Renew. Sustain. Energy Rev., 149: Article 111379, 10.1016/j.rser.2021.111379
12. Zhou Y, Wang Y, Li Y, Zwahlen F, Boillat J (2013) Hydrogeochemical characteristics of central Jianghan Plain, China. Environ Earth Sci 68:765–778.
13. Ngah SA, Nwankwoala HO (2013) Iron (Fe^{2+}) occurrence and distribution in groundwater sources in different geomorphologic zones of Eastern Niger Delta. Arch Appl Sci Res 5(2):266–272.
14. WHO (2003a) Chromium in Drinking-Water, Background document for preparation of WHO Guideline for drinking water quality. Geneva. World Health Organization. (WHO/ SDE/ WSH/03.04/4)
15. WHO (2003b) Zinc in Drinking-Water, Background document for preparation of WHO Guideline for drinking water quality. Geneva. World Health Organization. (WHO/ SDE/WSH/03.04/ 17)
16. Papachristodoulou C, Stamoulis K, Tsakos P, Vougidou C, Vozikis V, Papadopoulou C, Ioannides K (2015) Liver concentrations of copper, zinc, iron and molybdenum in sheep and goats from Northern Greece, determined by energy-dispersive X-ray fluo- rescence spectrometry. Bull Environ Contam Toxicol 94(4):460–467.
17. BIS (2012) Indian standard drinking water specification (Second revision). Bureau of Indian Standards (BIS) IS 10500, New Delhi.
18. WHO (2011a) Lead in Drinking-Water, Background document for preparation of WHO

Guideline for drinking water quality. Geneva. World Health Organization. (WHO/SDE/WSH/03.04/ 09/Rev/1)
19. WHO (2011b) Manganese in Drinking-Water, Background document for preparation of WHO Guideline for drinking water quality. Geneva. World Health Organization. (WHO/SDE/WSH/03.04/ 104/Rev/1)
20. Zhang Y, Lin YP (2014) Leaching of Lead from new unplasticized polyvinyl chloride (uPVC) pipes into drinking water. Environ Sci Pollut Res. 22(11):8405–8411. doi: 10.1007/s11356-014- 3999-9
21. Dahl C, Søgaard AJ, Tell GS, Flaten TP, Hongve D, Omsland TK, Aamodt G (2014) Do cadmium, lead, and aluminum in drinking water increase the risk of hip fractures? A NOREPOS Study. Biol Trace Elem Res 157(1):14–23
22. Bartlett L, Vesilind PA (1998) Expediency and human health: the regulation of environmental chromium. Sci Eng Ethics 4(2):191–201.
23. Umar M, Waziri M, Hati SS (2013) Explanatory interaction profile of Cd, Pb and Zn on the relative abundance of Fe as response variable in drinking water quality assessment. Int Res J Pure Appl Chem 3(4):404–416.
24. ATSDR (Agency for Toxic Substances and Disease Registry) (2005) Toxicological profile for zinc. US Department of Health and Human Services, Washington.
25. Al-Subu MM, Haddad M, Mizyed N, Mizyed I (2003) Impact of irrigation with water containing heavy metals on soil and groundwater—a simulation study. Water Air Soil Pollut 146(1–4):141–152
26. Mirlean N, Baisch P, Medeanic S (2009) Copper bioavailability and fractionation in copper-contaminated sandy soils in the wet subtropics (Southern Brazil). Bull Environ Contam Toxicol 82(3):373–377
27. Kanmani S, Gandhimathi R (2013) Investigation of physicochemical characteristics and heavy metal distribution profile in ground- water system around the open dump site. Appl Water Sci 3(2):387–399.
28. USEPA (1995) Technical factsheet on nickel. US Environmental Protection Agency, Washington
29. Purushotham D, Rashid M, Lone MA, Rao AN, Ahmed S, Nagaiah E, Dar FA (2013) Environmental impact assessment of air and heavy metal concentration in groundwater of Maheshwaram watershed, Ranga Reddy district, Andhra Pradesh. J Geol Soc India 81(3):385–396.
30. Helena B, Pardo R, Vega M, Barrado E, Fernandez JM, Fernandez L (2000) Temporal evolution of groundwater composition in an alluvial aquifer (Pisuerga River, Spain) by principal component analysis. Water Res 34(3):807–816
31. Mudgal KD, Kumari M, Sharma DK, devMudgal K, Kumari M (2009) Hydrochemical analysis of drinking water quality of Alwar district, Rajasthan. Nat Sci 7(2):30–39.
32. Sappa G, Ergul S, Ferranti F (2014) Geochemical modeling and multivariate statistical evaluation of trace elements in arsenic contaminated groundwater systems of Viterbo Area, (Central Italy). SpringerPlus 3(1):237
33. Mahipal S S, Rajeev K (2019) Contaminant of Heavy Metals in Groundwater & its Toxic Effects on Human Health & Environment. Int J Environ Sci Nat Res 18(5): 555996.