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Assessment of Heavy Metal Distribution in Groundwater in and around Gulf of Mannar Seashore Area Using GIS Technique

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Abstract

The present study was carried out to analyze the heavy metal level of 25 bore and duck wells located at the different localities in and around Gulf of Manner seashore area during the period of pre monsoon, monsoon and post monsoon seasons. Arsenic (As), Manganese (Mn), Zinc (Zn), Cadmium (Cd), Chromium (Cr), Copper (Cu), Mercury (Hg) and Lead (Pb) concentrations in groundwater were analyzed by Atomic absorption spectrometer. The results were compared with drinking water standard prescribed by WHO, BIS, ICMR and FAO. This study shows that most of samples has high concentration of heavy metals (exceeds maximum permissible limit). A slight increment in concentration of individual metals is produced in summer season than in winter season. This study shows that all samples contains high concentrations of Hg, Pb and Mn above the maximum permissible limits as prescribed by WHO, BIS, ICMR and FAO. The spatial distributions of heavy metal in ground water were taken to Geological Information System (GIS). In Arc GIS, spatial distribution maps were prepared for the above analyzed heavy metals.

Keywords: Groundwater, Gulf of Mannar, Heavy Metal, Arc GIS.

Introduction

Water is a vital source of life which is essential for survival of all living organisms. Water is not only the most important essential constituent of all animals, plants and other organisms but also the pivotal for the survivability of mankind in the biosphere[1]. Ground water occurs almost everywhere beneath the earth surface not only in a single widespread aquifer, but also in thousands of local aquifer systems[2]. Several factors such as climate, characteristics of soil, circulation of ground water through rock types, topography of the area, intrusion of saline water in coastal areas, human activities on the ground etc. posses several effects on the quality of water[3]. Safe and good quality drinking water is the basis for good human health. Water provides some elements, but when polluted it may dangerous to human health and cause disease such as various cancers, adverse reproductive outcomes, cardiovascular disease and neurological disease[4]. Some heavy metals such as Cu, Fe, Mn, Ni and Zn are compulsory micronutrients for flora –fauna and microbes. Besides metal like Cd, Cr and Pb are harmful beyond a certain limit[5]. Therefore the heavy metal concentration in drinking water should be kept in low ppb range. One of the most hazardous trace metal found in drinking water is arsenic (As) being both toxic and carcinogenic[6].

GIS has emerged as a powerful technology for instruction, for research and for building the structure of programs[7]. In the present study, 25 bore and duck well ground water samples have been collected from Gulf of mannar sea shore area in pre monsoon, monsoon, and post monsoon and analyzed various heavy metals like Mn, Cd, As, Hg, Cu, Cr, Pb and Zn by atomic absorption spectrometer (Model VAIRAN AA240). The analyzed results were taken into Arc GIS environment. In GIS spatial distribution maps were prepared for the analyzed metal in three seasons like pre monsoon, monsoon, and post monsoon (figure 2, 3 and 4).

Study Area: The Gulf of mannar (figure 1) which is the first marine Biosphere Reserves established in India, lies between India and Srilanka and covers an area of about 10,500sq.Km. It includes 21 coral islands located between 8 46’ and 9 14’N latitude and 78 9’ and 79 14’ longitude. The Gulf Manner (GoM) located in southeast coast of India surrounded by a chain of 21 islands starting from holy town of Rameswaram and ending at the industrial town of Tuticorin. The GoM has been declared as the “marine biosphere reserve in 1989 and consists of 3269 species of flora and fauna, including 377 species that are endemic to the region”[8]. The Gulf of Mannar (GoM) is one of the coral reefs rich regions in India. The Gulf of Mannar is considered as “Biologists Paradise” for; it has 3600 species of flora and fauna. The mangrove habitats in the Gulf of Mannar have 9 different species of vegetation supporting a variety of marine fauna including sea birds and sea snakes. The GoM is heavily threatened by the discharge of sewage from human settlements and effluents from industries. In addition, extensive land use and urban sprawl are major environmental concerns affecting the health status of GoM. Due to suitability of these coasts for major developmental activities and the establishment of industries, ports, harbors and tourism facilities in and around, the GoM has attracted an increased human settlement along the

coast and resulted in stress on the fitness of GoM[9]. Thus this study was aimed to assess metal distribution pattern among the 25 bore and duck well samples of GoM.

Material and Methods

Water samples were collected in 5L polythene container from 25 different localities (table 1) in Gulf of mannar sea shore (from Ramanathapuram to Tuticorin) area. Before collecting the sample, polythene containers cleaned by soaking it in 10% nitric acid over night washed and rinsed with distilled water on the day of sampling. At the sampling site, the bottles were rinsed twice with the water being sampled, prior to the filling. One ml of con.HNO_3 is added to each sample. The samples are filtered immediately upon arrival at the laboratory, using a 0.45µm Millipore membrane filter[10] and the water samples are stored in the laboratory at 4ºC. An aliquot sample is taken into beaker, further it is digested on a hot plate and reduced to a volume less than 50ml. The digested sample is poured into a 50ml volumetric flask and made up by distilled water, which is used before to rinse the digested sample beaker[11]. The prepared sample is kept in the dark place and the trace elements were analyzed by using Atomic Absorption Spectrometer[12,13] using air –acetylene flame. Operational conditions were adjusted in accordance with the manufacturer's guidelines to yield optimal determination. Quantification of metals was based upon calibration curves were determined several times during the period of analysis. The detection limits for manganese, copper, chromium, lead, cadmium, zinc are 0.001, 0.001, 0.004, 0.002, 0.01, 0.005, 0.008mg/litr respectively.

Results and Discussion

The variation in the concentration of trace metal (Mn, Cd, As, Hg, Cu, Cr, Pb and Zn) in the groundwater during pre monsoon, monsoon and post monsoon of study area was evaluated. The obtained results of heavy metal analysis are reported in table 3, 4 and 5 respectively. A measurements and analysis shows that rocks weathering and anthropogenic inputs are found to be the main sources for heavy metals in ground water[14]. The concentrations of heavy metals were compared with drinking water standard prescribed by WHO, BIS, ICMR and FAO (table 2).

Table-1
Sampling Area in Gulf of Mannar Seashore Area

Sample No	Sampling Locations	Type of well
GoM1	Rameshwaram Koil (Nalatheertham)	Open well
GoM2	Sathya Nagar (Rameshwaram)	Open well
GoM3	Pamban	Open well
GoM4	Mandapam	Open well
GoM5	Seeniyappa Tharga	Open well
GoM6	Pirappan Valasai	Open well
GoM7	Uchipuli	Open well
GoM8	Ramanathapuram (Bharathinagar)	Open well
GoM9	Kilakarai	Open well
GoM10	Ervadi	Open well
GoM11	Idhambadal	Pond
GoM12	Sikkal	Open well
GoM13	Sayalkudi	Tube well
GoM14	Narippayur	Open well
GoM15	Vembar	Open well
GoM16	Melmanthai	Tube well
GoM17	Srivaigunda perumalpuram	Open well
GoM18	Veppalodai	Tube well
GoM19	Pattinamaruthur	Open well
GoM20	Tharuvaikulam	Open well
GoM21	Devispuram	Open well
GoM22	Therkusottan thoppu	Open well
GoM23	Saramani Street (Tuticorin)	Tube well
GoM24	Natarajapuram (Tuticorin)	Tube well
GoM25	Keelarathaveethi (Tuticorin)	Open well

Table-2
Drinking Water Standards

Metals	BIS(IS1050 – 91) (mg/l)		BIS (IS10500 – 91) Revised 2003 (mg/l)	ICMR (mg/l)	WHO (mg/l)	FAO (For irrigation) (mg/l)
	Desirable Limit	Maximum Permissible limit	Desirable Limit	Desirable Limit	Desirable Limit	Desirable Limit
Mn	0.1	0.3	0.1	50	0.1	0.2
Cd	0.01	0.01	0.01	-	0.005	0.1
As	0.05	0.05	0.01	-	0.05	5
Hg	0.001	0.001	0.001	-	0.001	-
Cu	0.05	1.5	0.05	0.05	1	0.2
Cr	0.05	0.05	0.05	-	0.05	0.1
Pb	0.05	0.05	0.05	-	0.05	-
Zn	5	15	5	0.1	5	2
Ni	-	-	-	-	-	0.2
Mo	-	-	-	-	-	0.01
Co	-	-	-	-	-	0.05
Fe	0.3	1	0.3	0.1	0.3	5

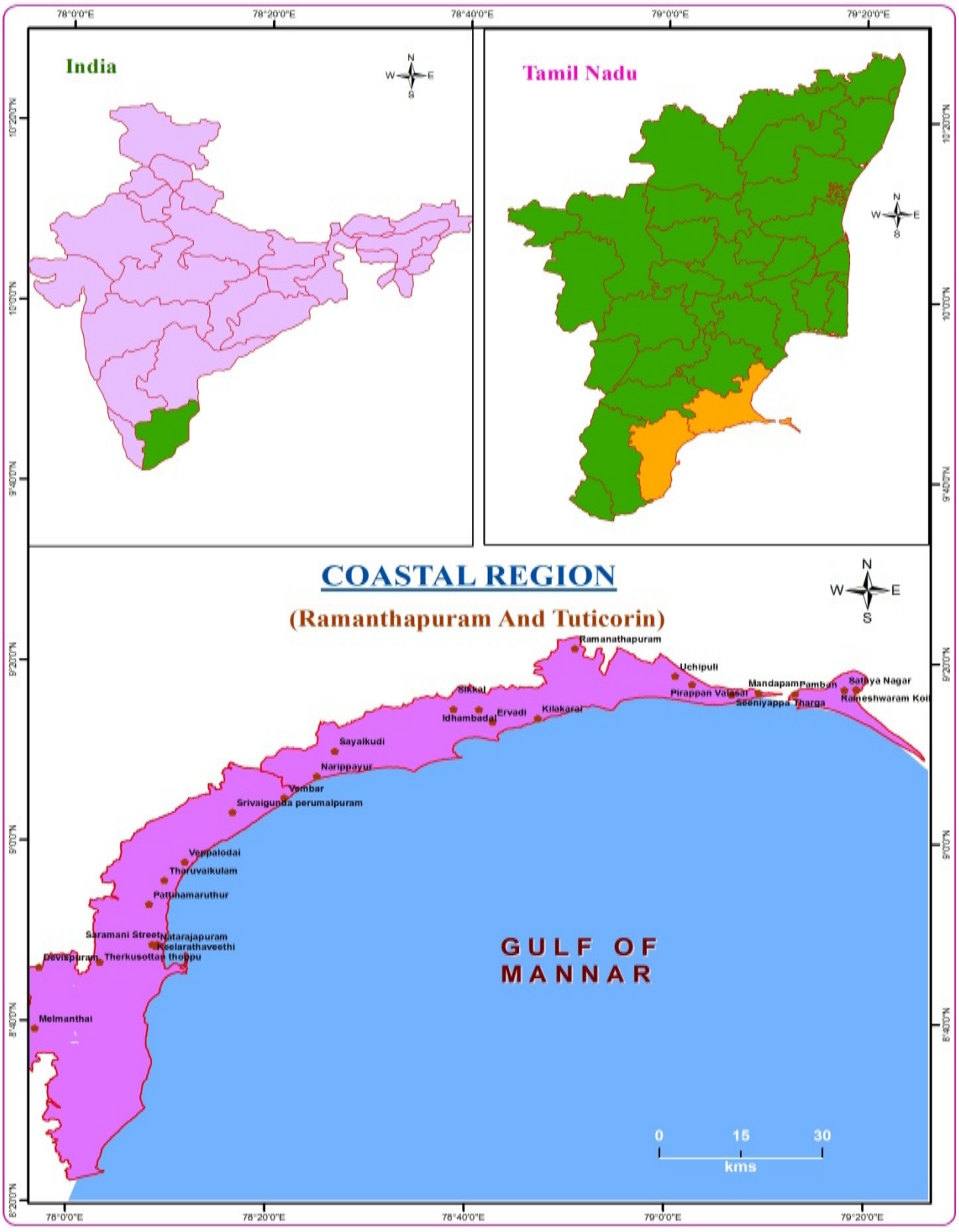


Figure-1
Location of Study area

Table-3
Heavy Metal contents (ppm) in groundwater during pre monsoon

Sample Number	Mn	Cd	As	Hg	Cu	Cr	Pb	Zn
GoM1	0.065	0.005	0.003	0.4	0.026	0.007	0.063	0.342
GoM2	0.068	0.006	0.006	0.8	0.019	0.005	0.057	0.301
GoM3	0.073	0.005	0.003	0.3	0.019	0.007	0.046	0.297
GoM4	0.061	0.004	0.003	0.041	0.018	0.007	0.312	0.287
GoM5	0.058	0.006	0.003	0.021	0.018	0.005	0.049	0.296
GoM6	0.061	0.007	0.004	0.011	0.019	0.007	0.051	0.289
GoM7	0.081	0.003	0.005	0.012	0.026	0.004	0.15	0.283
GoM8	0.15	0.003	0.006	0.015	0.026	0.006	0.234	0.487
GoM9	0.15	0.002	0.008	0.016	0.037	0.005	0.367	0.286
GoM10	1.27	0.02	0.006	0.013	0.062	0.009	0.287	0.71
GoM11	0.07	0.004	0.004	0.011	0.047	0.008	0.298	0.49
GoM12	1.34	0.006	0.004	0.014	0.038	0.007	0.274	0.59
GoM13	1.57	0.012	0.003	0.016	0.048	0.005	0.175	0.47
GoM14	1.89	0.003	0.004	BDL	0.039	0.005	0.254	0.38
GoM15	0.11	0.005	0.003	BDL	0.051	0.006	0.386	0.242
GoM16	0.097	0.05	0.004	BDL	0.062	0.006	0.345	0.332
GoM17	1.37	0.03	0.003	BDL	0.063	0.007	0.321	0.253
GoM18	2.23	0.04	0.006	BDL	0.036	0.008	0.572	0.562
GoM19	1.43	0.06	0.007	BDL	0.047	0.009	0.473	0.791
GoM20	1.49	0.07	0.007	BDL	0.031	0.004	0.431	0.782
GoM21	1.88	0.04	0.009	BDL	0.079	0.004	0.783	0.772
GoM22	0.08	0.03	0.02	0.23	0.093	0.002	0.856	1.452
GoM23	0.09	0.08	0.05	0.45	0.092	0.006	0.875	1.571
GoM24	0.06	0.12	0.007	BDL	0.091	0.005	0.853	1.281
GoM25	1.95	0.01	0.009	BDL	0.091	0.005	0.771	1.356

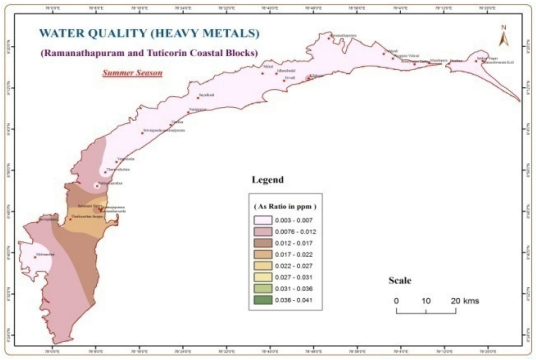
Table-4
Heavy Metal contents (ppm) in groundwater during monsoon

Sample Number	Mn	Cd	As	Hg	Cu	Cr	Pb	Zn
GoM1	0.059	0.003	0.002	0.12	0.018	0.006	0.049	0.288
GoM2	0.077	0.009	0.006	0.93	0.035	0.008	0.058	0.298
GoM3	0.069	0.004	0.003	0.21	0.019	0.007	0.047	0.292
GoM4	0.059	0.004	0.002	0.041	0.01	0.005	0.248	0.269
GoM5	0.055	0.006	0.003	0.017	0.017	0.004	0.475	0.279
GoM6	0.061	0.007	0.004	0.011	0.019	0.003	0.05	0.281
GoM7	0.073	0.003	0.005	0.012	0.03	0.005	0.14	0.269
GoM8	0.12	0.003	0.006	0.011	0.025	0.006	0.219	0.469
GoM9	0.123	0.002	0.008	0..013	0.032	0.005	0.358	0.279
GoM10	1.23	0.02	0.005	0.011	0.058	0.009	0.237	0.652
GoM11	0.08	0.004	0.003	0.011	0.045	0.006	0.246	0.456
GoM12	1.34	0.005	0.003	0.012	0.037	0.005	0.258	0.57
GoM13	1.56	0.009	0.002	0.013	0.047	0.005	0.157	0.456
GoM14	1.88	0.002	0.002	0.009	0.037	0.003	0.228	0.36
GoM15	0.1	0.005	0.002	BDL	0.051	0.005	0.269	0.237
GoM16	0.088	0.05	0.004	BDL	0.059	0.006	0.328	0.0326
GoM17	1.38	0.03	0.003	BDL	0.065	0.007	0.32	0.249
GoM18	2.28	0.04	0.005	BDL	0.039	0.007	0.569	0.555
GoM19	1.48	0.06	0.006	BDL	0.047	0.007	0.439	0.789
GoM20	1.48	0.06	0.007	BDL	0.029	0.004	0.429	0.701
GoM21	1.84	0.04	0.009	BDL	0.073	0.003	0.769	0.769
GoM22	0.08	0.03	0.02	0.23	0.083	0.002	0.828	1.349
GoM23	0.09	0.07	0.03	0.43	0.087	0.004	0.858	1.547
GoM24	0.06	0.09	0.006	BDL	0.089	0.004	0.839	1.271
GoM25	1.91	0.02	0.008	BDL	0.087	0.005	0.758	1.329

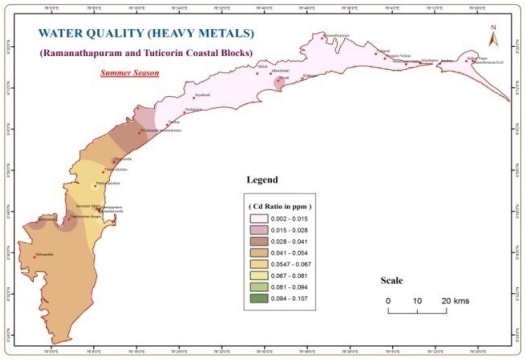
Table-5
Heavy metal contents (ppm) in groundwater during post monsoon

Sample Number	Mn	Cd	As	Hg	Cu	Cr	Pb	Zn
GoM1	0.058	0.002	0.001	0.1	0.015	0.005	0.046	0.281
GoM2	0.061	0.004	0.003	0.7	0.014	0.003	0.048	0.289
GoM3	0.067	0.003	0.002	0.2	0.017	0.006	0.041	0.286
GoM4	0.056	0.003	0.001	BDL	0.013	0.005	0.245	0.265
GoM5	0.054	0.005	0.002	BDL	0.016	0.004	0.047	0.276
GoM6	0.059	0.006	0.003	BDL	0.017	0.005	0.048	0.279
GoM7	0.071	0.002	0.004	BDL	0.02	0.003	0.12	0.267
GoM8	0.1	0.002	0.005	BDL	0.022	0.005	0.216	0.465
GoM9	0.12	0.001	0.007	BDL	0.032	0.004	0.354	0.276
GoM10	1.2	0.01	0.004	BDL	0.056	0.008	0.234	0.65
GoM11	0.06	0.003	0.003	BDL	0.043	0.006	0.243	0.45
GoM12	1.3	0.005	0.003	BDL	0.036	0.005	0.253	0.56
GoM13	1.51	0.009	0.002	BDL	0.045	0.004	0.153	0.45
GoM14	1.87	0.002	0.002	BDL	0.036	0.003	0.221	0.31
GoM15	0.09	0.004	0.001	BDL	0.048	0.005	0.267	0.231
GoM16	0.087	0.04	0.003	BDL	0.058	0.005	0.321	0.321
GoM17	1.34	0.02	0.002	BDL	0.061	0.006	0.301	0.243
GoM18	2.2	0.03	0.005	BDL	0.032	0.006	0.561	0.543
GoM19	1.43	0.05	0.006	BDL	0.043	0.007	0.431	0.786
GoM20	1.45	0.06	0.006	BDL	0.025	0.003	0.421	0.768
GoM21	1.8	0.03	0.009	BDL	0.071	0.003	0.765	0.765
GoM22	0.07	0.02	0.01	0.2	0.081	0.001	0.823	1.342
GoM23	0.08	0.07	0.03	0.4	0.085	0.004	0.854	1.541
GoM24	0.05	0.09	0.005	BDL	0.087	0.003	0.834	1.265
GoM25	1.9	0.01	0.008	BDL	0.086	0.004	0.756	1.324

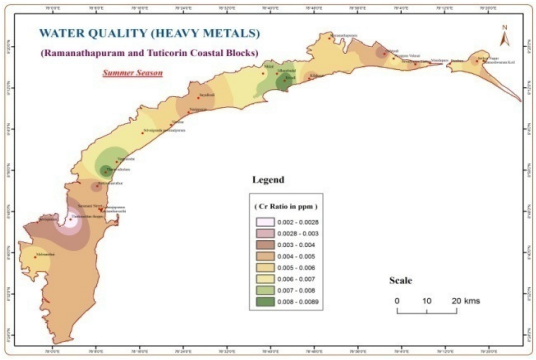
*BDL – Bellow the Deductable Limit



Arsenic in Pre-monsoon season



Cadmium in Pre-monsoon season



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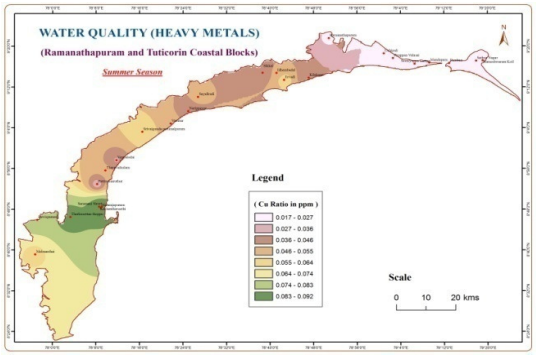
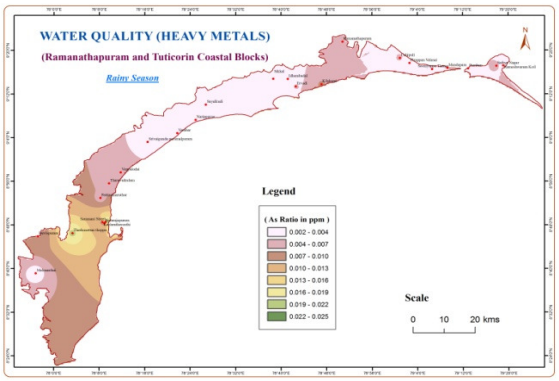
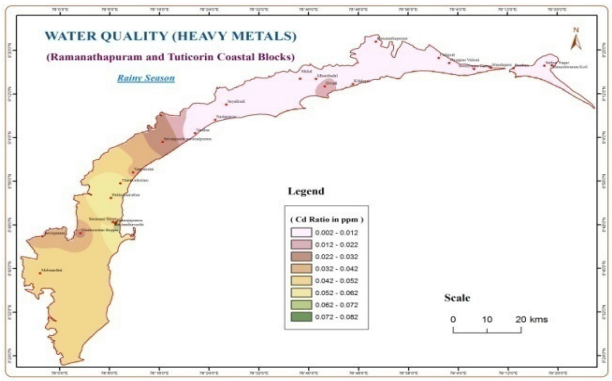


Copper in Pre-monsoon season

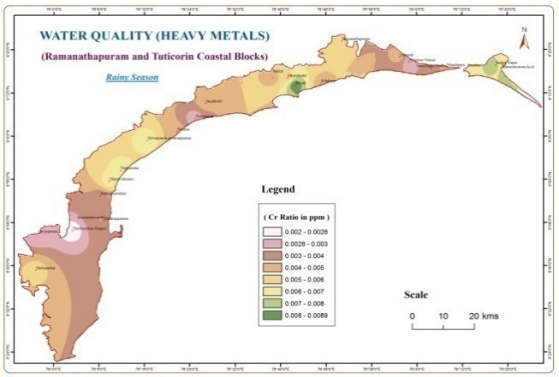
Figure-2
Spatial distribution of heavy metals during pre monsoon



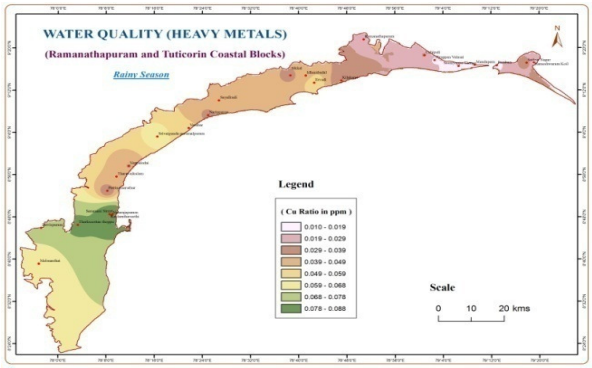
Arsenic in Monsoon season



Cadmium in Monsoon season

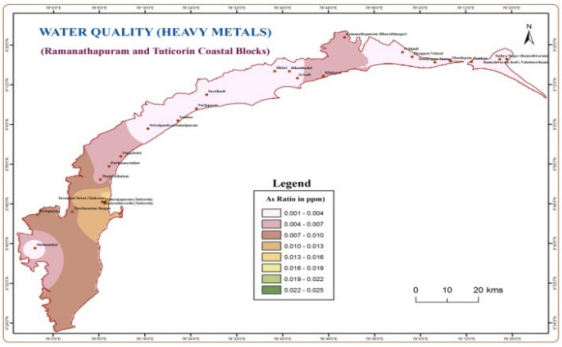


Chromium in Monsoon season

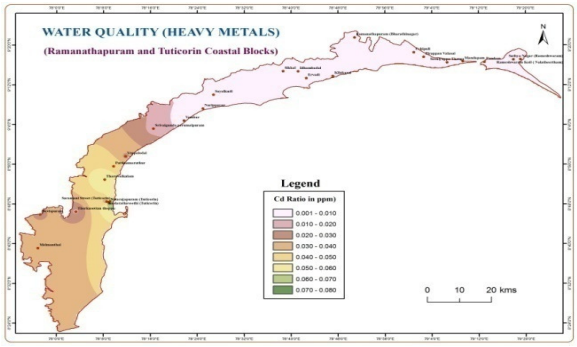


Copper in Monsoon season

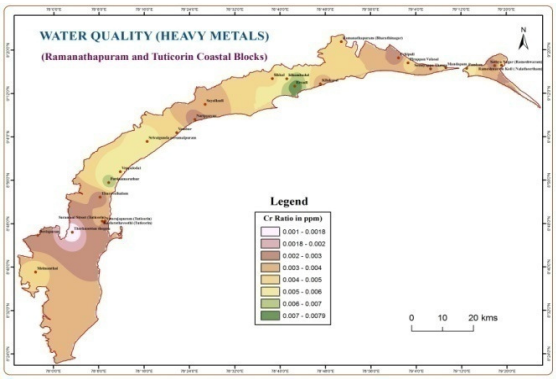
Figure-3
Spatial distribution of heavy metals during monsoon



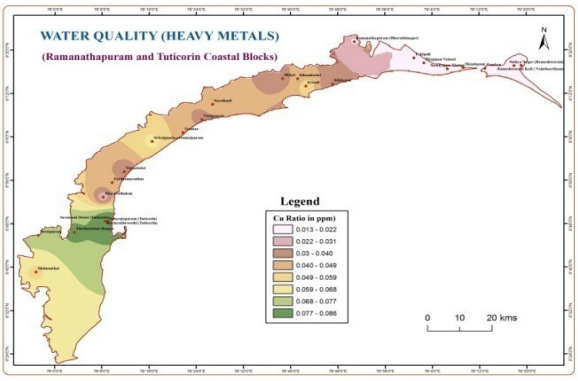
Arsenic in Post Monsoon season



Cadmium in Post Monsoon season



Chromium in Post Monsoon season



Copper in Post Monsoon season

Figure–4
Spatial distribution of heavy metals during post monsoon

Manganese: Manganese is an essential trace nutrient in all form of life. It is less toxic than those of other widespread metals such as nickel and copper[15]. However, exposure to manganese dusts and fumes should not exceed the ceiling value of 5mg/m^3 even for short periods because of its toxicity level. The variation of manganese at different sites during pre monsoon, monsoon and post monsoon are shown in Table 3, 4 & 5 respectively.

Cadmium: Cadmium is considered to be one among the environmentally hazardous metals, because of its high toxicity and greater capability of accumulation and retention in the body of organisms including human. In the present study, the cadmium concentration is in the range from 0.002 to 0.09ppm. The maximum acceptable limit for cadmium in drinking water is 0.005ppm[16]. Cd may be cause the diseases; hypertension, arteriosclerosis, cancer etc. Cd irreversibly accumulates in the human body, in particularly in kidneys and other vital organs such the lungs or the liver. In addition to its extraordinary cumulative properties,Cd is also a highly toxic metal that can disrupt a number of biological systems, usually at doses that are much lower than most toxic metal[17].

Arsenic: One of the most hazardous trace metal found in drinking water is arsenic (As) being both toxic and carcinogenic[18]. Long term intake of arsenic may give rise to skin lesions at concentration 50mg/litr. In the present study the arsenic concentration range from 0.001 to 0.05ppm. All sample from the study area has bellow the permissible limit prescribed by WHO, BIS, ICMR and FAO.

Mercury: Mercury is a toxic element and serves no physiological function in man ie., non essential element. In the present investigation, high mercury content observed in ground water is in the range from 0.011 to 0.8ppm. All samples in our study area has high content of mercury (above the maximum permissible limit prescribed by WHO,BIS, ICMR and FAO).

Copper: Copper is an essential substance to human life, but chronic exposure to contaminant drinking water with copper can result in the development of anemia, liver and kidney dmage[19]. Copper in large doses is dangerous to infants and people with certain metabolic disorders. On the other hand, lack of copper intake causes anemia, growth inhibition and blood circulation problems[20]. In this present study area, the concentration of copper content range in ground water from 0.014 to 0.091ppm. This study shows all samples has bellow level of copper than permissible limit prescribed by WHO, BIS, ICMR and FAO).

Chromium: Chromium is naturally occurring element which is essential to animal and human. i.e synthesis of fat from glucose and also for oxidation of fat to carbon dioxide. Chromium in excess amounts can be toxic especially the hexavalent form. In this present study area, the concentration of chromium content range in ground water from 0.001 to 0.009 ppm. This study shows all samples has bellow level of chromium than permissible limit prescribed by WHO, BIS, ICMR and FAO).

Lead: Lead is a dangerous element; it is harmful even in small amount. Distribution of lead at different sites during pre monsoon and post monsoon are shown in table 2 and 3. The maximum lead content 0.875 ppm and minimum 0.041ppm have been recorded at different sites Gulf of Mannar sea shore area. This study shows most of the ground water sample has high lead content. i.e above the maximum permissible limit prescribed by WHO,BIS, ICMR and FAO).

Zinc: Zinc is an essential trace element found in virtually all food and potable water in the form of salts or organic complexes. Zinc deficiency in human body may results in infantilism, impaired wound healing and several other diseases[21]. The values of zinc concentration obtained in this study, range from 0.231 to 1.571ppm. Zinc content in all sampling sites, are within the permissible limit.

Conclusion

The concentrations of heavy metals like Mn, Cd, As, Hg, Cu, Cr, Pb and Zn have been determined by using Atomic Absorption Spectroscopy during pre monsoon, monsoon and post monsoon. Based on the experimental data, the concentration of heavy metals during pre monsoon is high compared to post monsoon. This is due to evaporation during pre monsoon. This study shows that, most of the groundwater samples have high content of Hg, Mn, Pb, Cd and Cu. The heavy metal concentration has been displayed by mapping during post monsoon, monsoon and pre monsoon. On the basis of above discussion it may conclude that the underground drinking water at almost all sites in Gulf of Mannar is highly contaminated. Therfore the use of ordinary hand pump and borewell should be discouraged. People dependants on this water are often prone to health hazards due to contaminated potable water. Therefore indigenous technologies should be adopted to make water fit for purpose.

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