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Full Length Research Paper

Heavy metal characteristics of groundwater in Ibadan South Western, Nigeria

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Water, an essential commodity is consequently being affected by natural and human activities. Investigations were made on groundwater of the study area to evaluate the impact of heavy metals. Groundwater samples were collected and analyzed using Inductively coupled plasma- emission spectrometry method, at Acme laboratories Canada. Geochemical analysis revealed a significant concentration of increasing order K > Ca > Mg > Fe > Zn > Cu > Pb > As > Cd. Ca, Fe and K were above the WHO standard. Index of geo-accumulation (Igeo), revealed no contamination of the trace metals. Inter-elemental analysis showed a strong correlation between Cd to Zn ('r'- 0.983) and Fe to Pb ('r'- 0.900), indicating that the metals are governed by the same geochemical factors and are from the same anthropogenic source. Piezometric map revealed southwest direction of groundwater flow that shows direction of contamination influx. The study can then be concluded to be contaminated with Ca, Fe and K due to the impact of man's activities in the environment. Public health effect of these metals could be anemia, kidney damage, brain damage, cancer and ultimately death.

Key words: Water, contamination degree, geochemical factors, public health, heavy metal.

INTRODUCTION

Earth is unique among other planets in the solar system since it has an environment where it has been able to thrive. Pure water rarely occurs in nature due to the capacity to dissolve numerous substances of heavy metals in large amounts (Brown, 1971). One of the major problems the public faces is contamination of drinking water. There are many industries that may or have contributed to the contamination of waterways by discharging toxic metals into rivers and streams. These heavy metals gets into the environment by air emissions from smelters, industrial smokes, waste incinerators, lead in household plumbing, old house paints and industrial waste (Tijani, 2000; Tijani et al., 2004; Odewande and Abimbola, 2008; Makinde, 2008; Golia et al., 2008). Toxicity levels of heavy metals depend on the type, its biological role, and the type of organisms that are exposed to it (Tijani et al., 2006); the kind of metals linked most often to human poisoning are lead (Pb), mercury (Hg), arsenic (As) and cadmium (Cd). In Nigeria, two sectors (food and processing sector) accounted for nearly half (47.9%) of total polluted wastewater discharges from the Nigerian industry in 1994 (World Bank, 1998a). Public health concerns are high with respect to the pollution effects of industrial water waste since majority of Nigerians still lack access to safe drinking water.

Groundwater accounts for about 98% of the world's fresh water and it is fairly well distributed throughout the world (Bouwer, 2002). It is intensively exploited for private, domestic and industrial uses in many urban centers, at the same time the sub-surface has come to serve as a receptor for many industrial and urban wastewaters and for solid waste disposals (World Bank, 1998a). This plays a fundamental role in shaping the economic and social health of the inhabitants. Ground-

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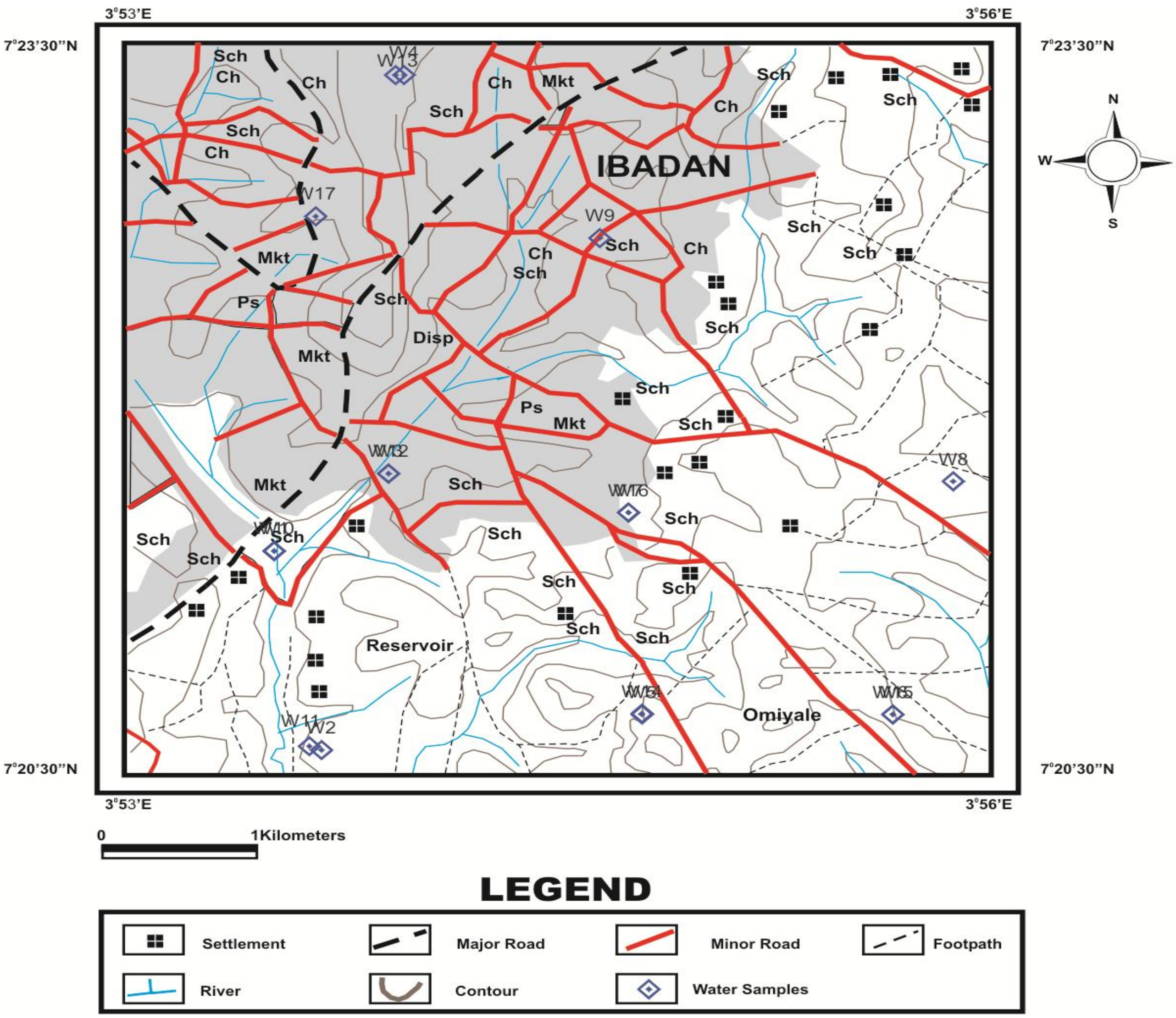

Figure 1. Study area with sample location points.

water is the only common and reliable water resources for urban usage in Ibadan metropolis. Ibadan is characterized by increasing trend in water consumption, due to intensive urbanization. Human activities and seepage of hazardous materials into underground wells had affected groundwater qualities (Subba et al., 2001; Odewande et al., 2008). Various studies was carried out on groundwater portability and chemical processes responsible for poor groundwater quality (Ajibade et al., 2011; Odukoya et al., 2009), and was concluded that uncontrolled population growth is a major factor to the groundwater contamination of Ibadan metropolis.

The study was therefore aimed at determining the groundwater characteristics of Ibadan South East, by evaluating the possible source of pollution, thus, assessing the portability of groundwater in the area, by comparison with the World Health Organization (WHO) standards, and to suggest the best remedial methods where necessary.

MATERIALS AND METHODS

Study location

The study area lies within longitude 3° 53' and 3° 56' E and latitude 7° 20' 30" and 7° 23' 30" N, (Figure 1) and lies within the basement complex of Southwestern Nigeria, the area is underlain by quartzite, migmatite, augen and banded gneiss, with some minor rocks like pegmatite, quart-schist and schist. The total available storage of groundwater in crystalline rock aquifers is limited by the rock type, weathering characteristics and structures. The area is easily accessible through a series of interconnecting minor roads, footpaths and a few major roads, with an uneven distribution of

Figure 2. Hand-dug wells in the study area.

topography (fairly lowlands to highlands). It has a tropical climate which shows fairly wide seasonal and climatic variation in temperature and very dependent on the two prevailing air masses blowing over the country at different times of the year. Annual temperature is approximately 27°C and relative humidity is over 80% with mean rainfall being between 1500 to 1570 mm.

100 ml rubber bottle was used for water collection on the field to align with National water quality programs that recommends that water samples should be collected and stored in bottles made of Pyrex, hard rubber, polyethylene or other inert materials. Two drops of nitric acid (0.2 mg/l) was added to the samples collected for cation analysis to retain the metal content. A LF 95 WTW conductivity with its specified units were used for measuring the electrical conductivity, total dissolved solid, temperature and salinity while the pH meter was used for the pH measurement. Hydrochloric acid was used to acidify all the water samples and the sampling locations were recorded using a Garmin 72 GPS.

Water sample collection

Water samples were collected randomly from seventeen covered and cased, covered and uncased, uncovered and cased, uncovered and uncased hand dug wells (Figure 2). Heavy metal (major and trace) analysis was done on the water samples to evaluate the impact on groundwater.

Analytical methods

The samples were analyzed using the inductive coupled plasma mass spectrometry (ICP-MS) technique. This technique is a rapidly developing method and is even replacing the Atomic Absorption Spectrometry (AAS) in several applications. The sample analysis was carried out in Acme Analytical Laboratories, Canada.

Statistical evaluation

Geo-accumulation index was used to asses the rate of contamination of metals on groundwater of the study area, the equation is given thus:

Geo-accumulation index (Igeo)

Geo-accumulation index is used in assessing the rate of contamination. The index has six classes (Table 1). It is expressed as:

$$Igeo = \log_2 (C_n/1.5*B_n)$$

Where C_n = measured concentration of the element, B_n = World Health Organization standard, 1.5 = a constant allowed for natural fluctuation.

RESULTS AND DISCUSSION

Hydro-chemical evaluation

Physical parameters

Mean pH value (Table 2) for the groundwater samples (7.3) falls below the stipulated EPA (2007) and WHO

Table 1. Geo-accumulation index classes.

Class	Range	Indication/water quality
0	Igeo<0	Practically uncontaminated
1	0<Igeo<1	Uncontaminated to moderately contaminated
2	1<Igeo<2	Moderately contaminated
3	2<Igeo<3	Moderately to heavily contaminated
4	3<Igeo<4	Heavily contaminated
5	4<Igeo<5	Heavily to extremely contaminated
6	5<Igeo<	Exetremely

Table 2. Physical characteristics of the water samples.

Parameters	pH	Electrical conductivity (ds/cm)	Temperature (°C)	Salinity (%)	TDS (mg/l)
Minimum	6.33	109	27.2	0.01	37.4
Maximum	8.05	956	30.2	0.08	627.3
Standard deviation	0.53	281.22	0.90	0.02	186.58
Mean	7.3	372.9	28.3	0.0	223.0
Range	6.33-8.05	109-956	27.2-30.2	0.01-0.08	37.4-627.3
WHO 2006	6.5-8.5	1400			500
EPA 2009	6.5-8.5	1400			500
SON 2007	6.5-8.5	1000			500

Table 3. Major elements with their respective WHO standards.

Location	Ca (ppm)	Fe (ppm)	K (ppm)	Mg (ppm)
Olorunsogo	16.98	0.01	7.43	18.58
Oja Oba	42.61	0.01	102.7	12.58
Molete	139.9	0.01	64.08	25.03
Eyin Grammar	33	0.101	14.57	13.99
Kudeti	68.11	0.100	58.48	11.09
Oke Aremu	18.42	0.039	34.66	3.18
Owode	10.32	0.56	11.79	7.87
Muslim	104.3	0.066	140.3	23.15
Odingo	83.11	0.244	33.6	46.29
Ayeye	77.03	0.01	97.68	38.89
WHO 2006	75	0.3	1.0->12	100

(2006) permissible standards respectively (Chernyavskaya, 1993). The EC mg/l (109 to 956) and TDS dS/cm (37.4 to 627.3) were also found to be within the EPA (2007) permissible limits.

Chemical parameters

Major elements: The major element in parts per million (ppm) ranges from potassium K (7.43 to 148.70), calcium Ca (8.8 to 139.9), magnesium Mg (2.95 to 46.29) and iron Fe (0.01 to 0.56) with mean values of 53.69, 51.79, 16.99 and 0.07, respectively, and has an increasing order reveals K > Ca > Mg > Fe (Table 3). High concentration of Ca was observed when compared with WHO 2006 standard in Molete, Muslim Odinjo and Ayeye environ and this cloud be attributed to the indiscriminate dumping of refuse in the area and also the weathering of Ca-rich feldspar of rocks in the area, while anomalously high concentration of K was found in nearly all the location except Olorunsogo and Owode, the evidence of the high metal could be attributed to the weathering of K-feldspar

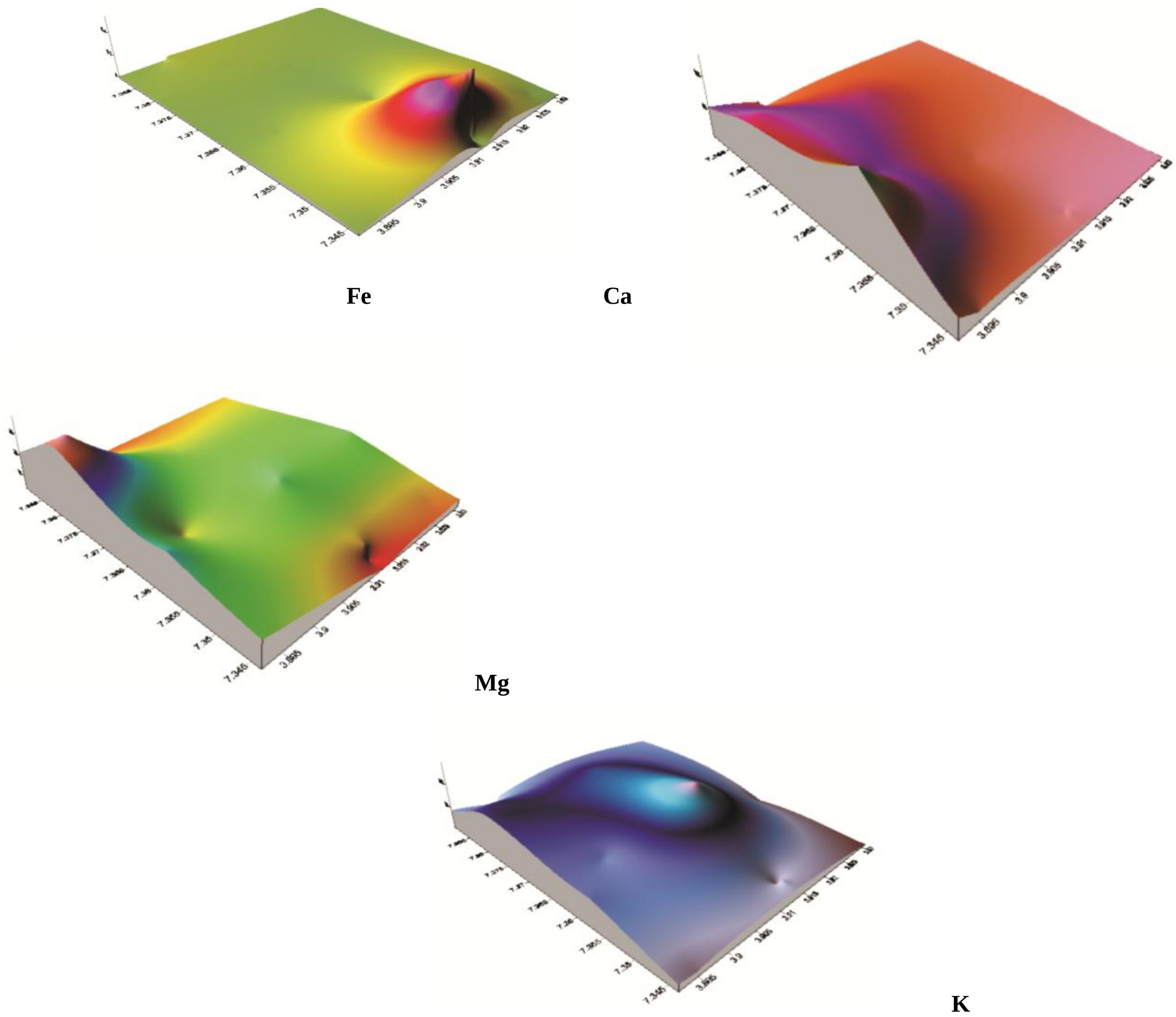

Figure 3. 3D representation of the geochemical map of the major metals.

in the study area. High Fe was noticed in Owode due to the waste dumped indiscriminately in the area. Mg and Fe were found within the permissible area in the study area. A 3D geochemical map (Figure 3) was also used to show the diagrammatical representation of the metals in the area.

Trace elements: Trace elements showed an increasing order Zn > Cu > Pb > As > Cd, the metals ranges from Zn (0.00 to 0.64), Pb (0.00 to 0.05), Cu (0.00 to 0.03), As (0.00 to 0.00) and Cd (0.00 to 0.00). Trace metals when compared (Table 4) with the WHO 2006 standard and was found to be within the permissible limits, thus the water of the study area could be termed to be safe for the public.

Inter-elemental analysis: Inter-elemental analysis ('r') showed (Table 5) arsenic As, calcium Ca, cadmium Cd and iron Fe to be strongly and positively correlated with almost all the major elements of the study areas, this revealed As to be of the governed by the same geochemical factor and also of the same anthropogenic source As-Ca r = 0.797, As-K r = 0.683, As- Mg r = 0.761, Ca-Cd r = 0.747, Ca-Mg r = 0.607, Ca-Zn r = 0.723, Cd-Zn r = 0.983, Fe-Pb r = 0.900.

Geo-accumulation index: Igeo of the trace elements revealed no contamination for the metals since all the metals were found to be below the value of 1 (Table 6).

Hydro-geologic interpretation: A piezometric map (Figure 4) was made to determine the groundwater flow; this was accomplished by determining the differences between the elevation and water level for the wells that showed the recharge and discharge zone in the study area. The map revealed a NE to SW flow direction which

Table 4. Trace elements with their respective WHO standards.

Location	As (ppm)	Cd (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)
Olorunsogo	0.0005	0.00005	0.002	0.0001	0.03
Oja Oba	0.0011	0.00005	0.006	0.0001	0.00
Molete	0.0018	0.00011	0.008	0.0008	0.64
Eyin Grammar	0.0005	0.00005	0.004	0.0024	0.09
Kudeti	0.0009	0.00005	0.009	0.0026	0.03
Oke Aremu	0.0005	0.00005	0.003	0.0038	0.06
Owode	0.0005	0.00005	0.010	0.0549	0.11
Muslim	0.002	0.00005	0.005	0.0018	0.09
Odingo	0.002	0.00005	0.002	0.001	0.03
Ayeye	0.0012	0.00005	0.003	0.0007	0.03
WHO 2006	0.01	0.003	2	0.01	3

Table 5. Correlation coefficient of heavy metals in the study area.

	As	Ca	Cd	Cu	Fe	K	Mg	Pb	Zn
As	1								
Ca	0.797	1							
Cd	0.440	0.747	1						
Cu	-0.219	-0.180	0.004	1					
Fe	-0.040	-0.148	-0.161	0 .050	1				
K	0.683	0.407	0.081	-0.117	-0.267	1			
Mg	0.761	0.607	0.239	-0.387	0.044	0.343	1		
Pb	-0.263	-0.281	-0.115	0.134	**0.900**	-0.276	-0.238	1	
Zn	0.396	0.723	0.983	0.000	-0.071	0.021	0.200	-0.011	1

Table 6. Geo-accumulation index for trace element in water samples.

Location	As	Cd	Cu	Pb	Zn
Olorunsogo	-0.097	-0.053	-0.187	-0.534	-0.127
Oja Oba	0.006	-0.053	-0.060	-0.534	-0.392
Molete	0.070	0.050	-0.028	-0.262	0.265
Eyin Grammar	-0.097	-0.053	-0.118	-0.118	0.008
Kudeti	-0.020	-0.053	-0.012	-0.108	-0.118
Oke Aremo	-0.097	-0.053	-0.162	-0.058	-0.052
Owode	-0.097	-0.053	0.009	0.291	0.035
Muslim	0.084	-0.053	-0.086	-0.156	0.009
Odingo	0.084	-0.053	-0.187	-0.232	-0.141
Ayeye	0.017	-0.053	-0.149	-0.279	-0.149

is the densely populated area and these revealed why some of the major and trace elements are above the permissible limits in the area.

Conclusion and recommendations

Major elements (Ca, Fe and K) were found to constitute a major factor of environmental pollution risk in the metropolitan southwest Nigeria. This study provides useful data on the present contamination outlook, on the basis of which pollution control and monitoring strategies and urban regional planning can be formulated in the study area.

A reasonable waste management policy and maintenance should be formulated to prevent the indiscriminate waste dump and sewage discharge.

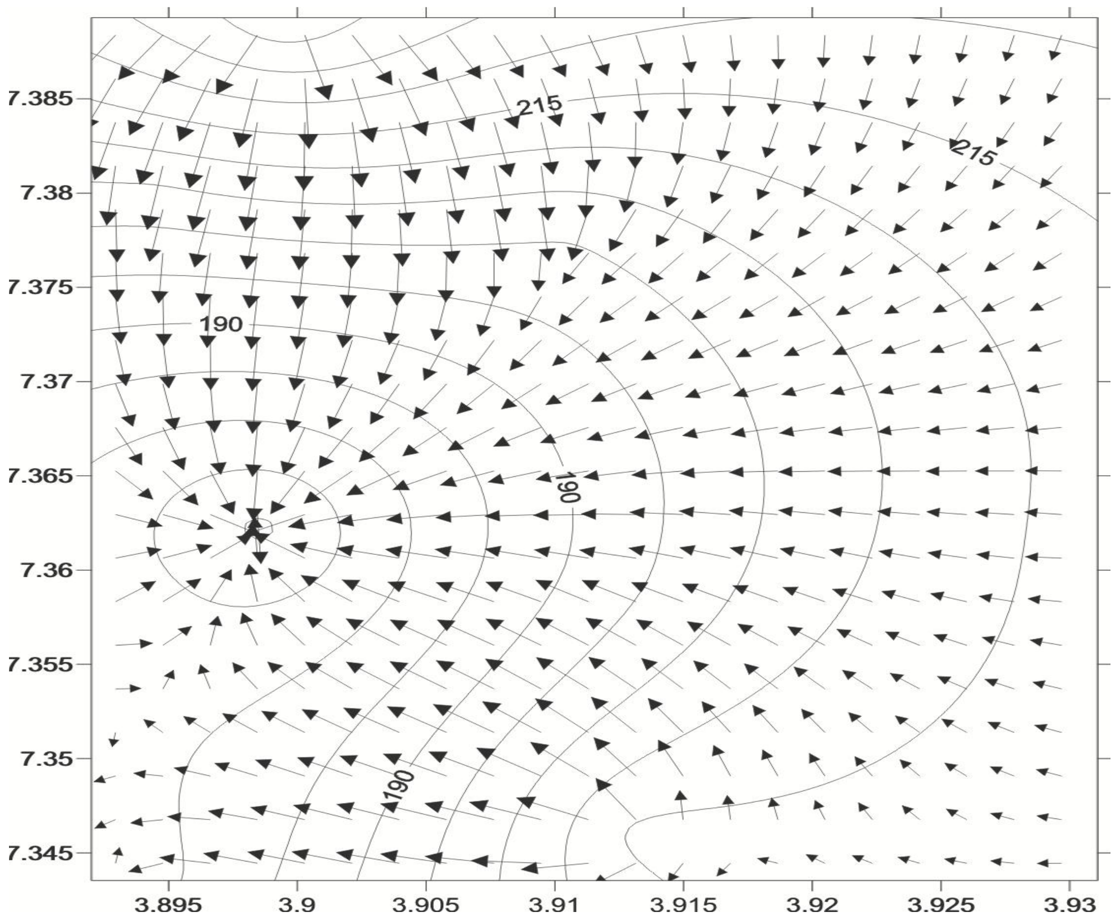

Figure 4. Piezometric map of study area.

Enough waste disposal system should be placed at strategic areas in the entire environment and strict measures should be made to ensure adequate obedience by the public.

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