POLLUTION ASSESSMENT OF PRIVATE BORE-HOLES WATER SUPPPLY USING CONTAMINATION INDEX AND CONTOUR IN OGBIA LOCAL GOVERNMENT AREA OF BAYELSA STATE, NIGERIA.

Abstract

The study focus on a pollution assessment of private boreholes water supply using contamination index and contour in Ogbia Local Government Area of Bayelsa State. Water samples from private boreholes were collected in accordance to APHA (2012) the samples were preserved in ice-park and taking to the laboratory within four hours from the time of collection. The borehole water samples were analyzed according to APHA (2012). The results of sample analyses were compared with WHO 2012 and NSWDQ 2007. The finding indicates that, the bacteriological parameter for sample locations 1,3,5,8,9,11 and 12 were all above the WHO 2012 and NSWDQ 2007 standards for drinking water quality. The result of the physico-chemical analyses indicates that, the temperature for all the sampling locations falls within AMBIENT limit, the colour for all the sampling locations is clear, pH for all the samples falls within the WHO 2012 and NSWDQ 2007 standard for drinking water, Turbidity, apart from sample 10 with 6.50 mg/l that is above the limit, all the other samples falls within the WHO 2012 and NSWDQ 2007standard for drinking water quality, Conductivity, apart from sample 12 with 682.50 mg/l that is above the limit, all the other samples falls within the WHO 2012 and NSWDQ 2007standard for drinking water quality, Chloride Cl, for all the samples falls within the WHO 2012 and NSWDQ 2007 standard for drinking water, Calcium Ca^{2+}, for all the samples falls within the WHO 2012 and NSWDQ 2007 standard for drinking water, Nitrate NO_3, for all the samples falls within the WHO 2012 and NSWDQ 2007 standard for drinking water, Nitrite NO_2, for all the samples falls within the WHO 2012 and NSWDQ 2007 standard for drinking water, TDS, for all the samples falls within the WHO 2012 and NSWDQ 2007 standard for drinking water, Salinity NaCI, for all the samples falls within the WHO 2012 and NSWDQ 2007 standard for drinking water, Total Hardness, for all the samples falls within the WHO 2012 and NSWDQ 2007 standard for drinking water, Calcium Hardness, apart from sample 12 with 56.00 mg/l that is above the limit, all the other samples falls within the WHO 2012 and NSWDQ 2007standard for drinking water quality, Magnesium Mg^{2+}, for all the samples falls within the WHO 2012 and NSWDQ 2007 standard for drinking water. These boreholes is required proper treatment before consumption.

Keywords: Pollution, Assessment, Water, Contamination and Index.

Introduction

Pollution is defined as an unfavourable alteration of the environment from the effects, changes in energy patterns, radiation level, chemical and physical constitution or the abundance of organism. Pollutants are generated by natural sources as well as human activities. Some are natural while others are human in origin. Pollutants if it is natural, has some adverse effects on human health. Pollutants are found mostly water, land and air (atmosphere) (Khopkor, 2007).Water plays an important role in social and economic development of an area. It's important in the economic sector has been highlighted. Doomkamp cited in Adinna, et al (2003) observed that without water, no economic endeavor is possible. Water also plays a very significant role in the health sector, agriculture, industries, commerce, tourism and recreation (Digha and Abua, 2018; Digha, 2021). The relevant of water in the social and health sector has been emphasized by the Nigerian Standard for Drinking Water NSDWQ (2007) and the World Health Organization WHO (2012) and had set standards for water quality for human consumption and other uses.

Water is vital to the existence of all living organism but this valued resources is increasingly being threatened as human population increases rapidly, the demand for more high quality water for domestic purposes and other economic activities also increases (Akoteyon and Omotayo, 2011). Unfortunately, human activities and land uses may result to contamination and deterioration in water quality that impact negatively not only on the aquatic ecosystem but also the availability of safe water for human consumption (Akoteyon and Omotayo, 2011). According to WHO (2012) that up to 80% of all sickness and diseases in the world are caused by inadequate supply of portable water or the use and consumption of polluted water. Contaminated water is the primary cause of diseases such as typhoid fever, diarrhea and dysentery in Nigeria. These diseases kill people and are very costly to the economy (Digha, 2008, Olukoya et al, 2019). In the Niger Delta, water Contamination by oil exploration activities is a big worry. It has led to the deteriorating condition of both the groundwater and the surface water, resulting to declining fish harvest and loss of biodiversity (Digha and Abua, 2018). Transmission of parasites and microbes in contaminated drinking water leads to infection of waterborne diseases. Disease sourced by bacteria and viruses like diarrheal and enteric are considered waterborne diseases in typhoid, cholera and intestinal parasites. The most dangerous parasitic infection includes amoebiasis hook worms and strongy loides (Gleick, 2002 and Jeontheau, 2009).

Groundwater that is contaminated with pathogens can lead to fatal fecal-oral transmission of diseases such as cholera and typhoid. In addition to the issue of pathogen, there is also the issue of Nitrate pollution to groundwater due to the sitting of pit latrines, which has led to numerous causes of methemoglobinemia (blue baby syndrome) in children. Also in areas that have naturally occurring high level of fluoride in groundwater which is used for drinking water, both dental and skeletal fluorosis can be prevalent and severe (Cole and Oria-us-fo, 2019). Moreso, another rapidly emerging risk factor is the visible form of environmental degradation which exposes groundwater sources by reason of the waste disposed through open surface landfills or open dumps. (Akujieze, and Oteze, 2006; and Akujieze and Ezomo, 2019, Ogungbile et al,2019). This study therefore assessed the magnitude of groundwater pollution in Ogbia Local Government Area using Contamination Index.

Study Area

Geographically, the study area is located between longitude 6^0 10^{11} and 6^0 28^{11}East of the Green wish meridian. It is bounded by latitude $4^0 35^{11}$and 5^0 00^{11} North of the equator, see figure 1. The study lies in Ogbia Local Government Area of Bayelsa State within the central Niger Delta of Nigeria. It is about 25km distance from the Atlantic Ocean and 8 km East of Yenagoa city. (Chima et al, 2007). The surface geology of the study area is made up of three tertiary lithostratigraphic units. The Benin, Agbada and Akata formations (Akpokodje, 1987). The central Niger Delta topography is characterized by a maze of effluents, creeks and swamps crisis-crossing the uniclinal low-lying plains in varying dimensions (Oyegun, 1999). The topographical terrain of the study area slopes from north-south direction; Oruma, Otusesga, Imiringi lying 6 meters above mean sea level while Olobiri at south lies 5 meters above mean sea level (Chima, and Digha, 2007; Chima, et al, 2007). The area is drained by large and small channels, rills, rivulets and streams of high tides. These rivers include, Anyama (Ekole Creek) Otuoke, Oloibiri, Abobiri, Emakalakala and the Kolo Creek. They all flow in North-South direction. Kolo Creek is distributary of the Orashi River which a branch of the River Niger. The Kolo Creek empties its water into Otuoke River via Abobiri River to Okoroma and finally leading to Twon-Brass into the Atlantic Ocean. The downstream of the Kolo Creek is influence by tidal movement. Communities like Otuogidi, Otuabagi, Otakeme, Otuagila and sometimes Kolo experience tidal movement of the water. The major industrial activity in the study area is oil exploration and exploitation. Oil fields from different location are connected to the Kolo Creek flow station which generates the Bayelsa State gas turbine for supply of electricity (Digha, 2008, Yaguo, et al, 2021).

The study area is characterized by two main seasons. The dry and wet seasons, with double maxima annual rainfall regime. The study area experiences heavy rainfall for about 8-9 months annually. The climate of the study area is 'A' type of Koppen's classification system (Oyegun, 1999). The weather condition of the area is control by the influence of the moist tropical maritime air mass and the dry dusty tropical continental air mass. The highest rainfall values are obtained in June (322.93 mm), August (438. 34 mm), and September (439. 84 mm).

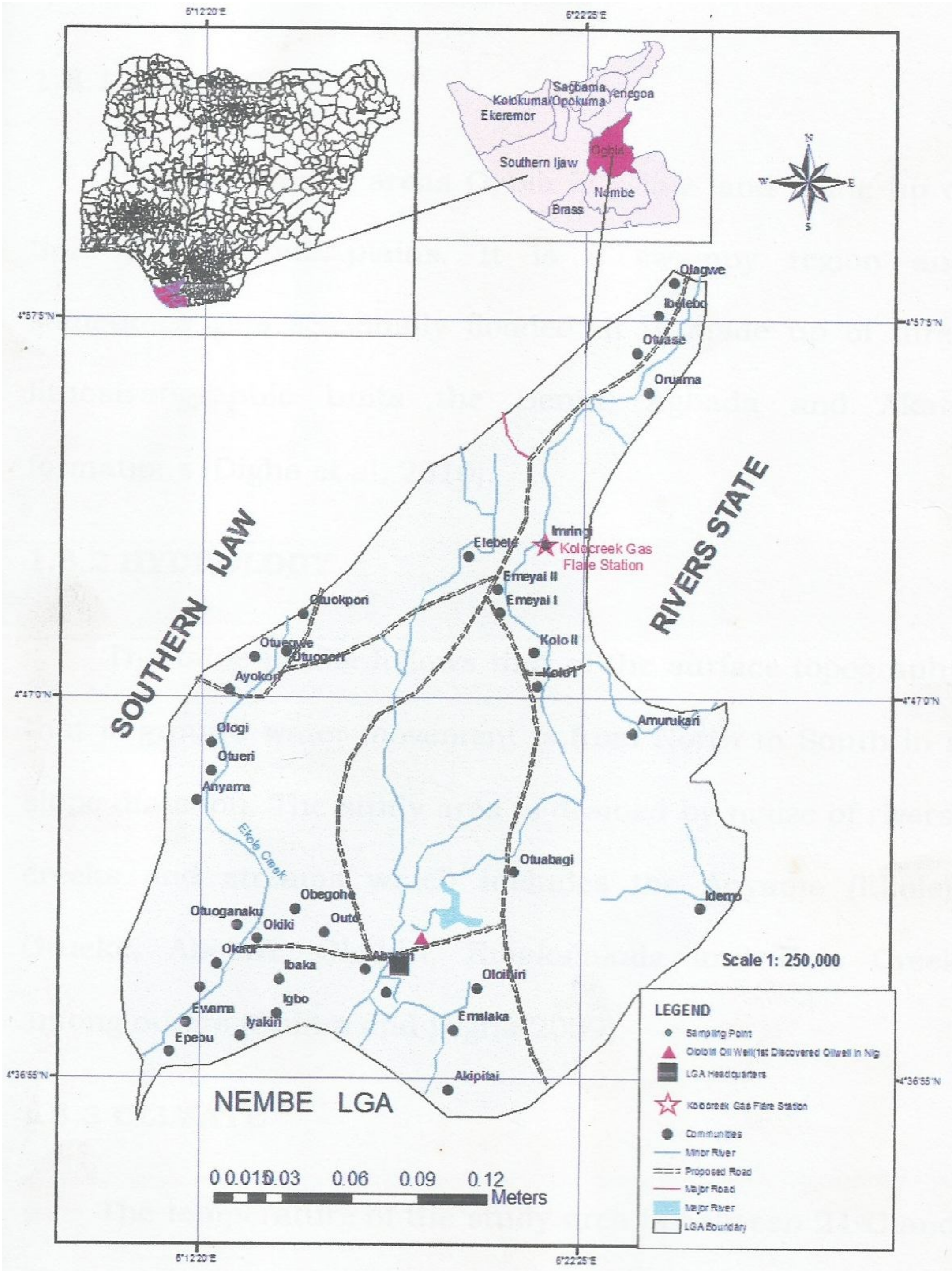

Fig. 1: Map of Ogbia LGA showing the study area

Materials and Methods

Sampling was done with the aid of Global positioning system (GPS) to take the location of sampling points. Water samples collected were preserve before taken to the laboratory for analysis as adopted from Oyem et al, (2014) and Park et al (2014).

Water samples meant for physicochemical analysis were collected from functional boreholes in 1-5 liters sampling bottles. Prior to samples collection, sample containers washed with neutral liquid and rinsed with distilled and deionized water according to APHA (2012).

Electrical conductivity was measured with a portable conductivity meter model 452D, the instrument was plugged and adjusted to a temperature and a standard solution with equivalent of 100 ms/cm was measured to obtain its reading. The samples were then measured at this temperature by inserting the conductivity cell into the samples. After each reading the conductivity cell was rinsed with distilled water to avoid transfer effect from the previous measurement. The EC value was read and recorded as adopted from Jimenez (2006).

The PH of the water samples was determined directly in the laboratory with a PH meter model 7010. The PH was used with a buffer solution of 4 to 7, the samples were then measured by inserting the electrode into the samples and the PH value was read and recorded after each measurement. The electrode was rinsed with distilled water to avoid transfer effect from the previous measurement as adopted from Jimenez (2006).

Water chemical properties were determined using flame photometer and atomic absorption spectrophotometer (AAS) transfer 100ml of the water into a larger beaker add 5m of concentrated HNO_3 evaporate on a stream both approximately 25ml, transfer to a 50ml acid – washed volumetric flask; bring to volume with deionized water analysed for Ca, Na, Mg, Cu, Ni, and using atomic absorption. As adopted from Suleiman and Audu (2014).

Results and Discussion

Table 1: **Shows data locations of boreholes and coliform concentrations in groundwater in Ogbia L.G.A of Bayelsa State (Rural).**

Community/Location	Longitudes	Latitudes	ColiDry	ColiWet	Averagecoli
Otuoke 1	**6.312889**	4.788556	98	7	52.5
Otuoke 2	**6.313111**	4.788083	0	0	0
Otuoke 3	**6.322222**	4.797889	7	37	22
Kolo 4	**6.375806**	4.810444	0	0	0
Kolo 5	**6.376639**	4.79775	140	29	84.5
Emyal I(6)	**6.354306**	4.830806	0	0	0
Emyal II(7)	**6.352139**	4.836833	0	0	0
Emyal II(8)	**6.354306**	4.841833	0	26	13
Elebele 9	**6.346556**	4.859111	0	7	3.5
Imiringi 10	**6.345389**	4.855667	0	0	0
Imiringi 11	**6.372528**	4.922083	0	27	13.5
Imiringi 12	**6.371944**	4.850944	108	0	54
WHO 2012			0	0	-
NSDWQ 2007			0	0	-

Table 1 indicate that Otuoke sample 1, the coliform bacteria for the dry season is 98 CFU/100 and wet season is 7 CFU/100 while the average coliform bacteria is 52.5 CFU/100. The result indicates that both wet season, dry season as well as average coliform count for Otuoke sample 1 were above the WHO 2011 and NSDWQ 2007 standards for drinking water quality. This implies that, consumption of water from this particular borehole has serious health negative implications. Otuoke sample 2, the dry season coliform bacteria is 0 CFU/100 while the wet season coliform bacteria is 0 CFU/100 and average coliform bacteria is 0 CFU/100. The results of Otuoke sample 2 shows that, the water from this borehole is free from bacteriological Contamination therefore it can be used for consumption and other domestic uses. The table indicates that Otuoke sample 3, dry season coliform count is 7 CFU/100, wet season coliform count is 37 CFU/100 while the average coliform count is 22 CFU/100. The results of Otuoke sample 3 further indicates that both the wet season, the dry season as well as average coliform count were above the WHO 2011 and NSDWQ 2007standards for drinking water quality. By implication, water from this borehole may have serious health implications thus, it must be treated before consumption.

Kolo sample 4, the dry season coliform bacteria is 0 CFU/100 while the wet season coliform bacteria is 0 CFU/100 and average coliform bacteria is 0 CFU/100. The results of Kolo sample 4 shows that, the water from this borehole is free from bacteriological contamination therefore it can be used for consumption and other domestic uses. Kolo sample 5, the dry season coliform bacteria is 140 CFU/100, and wet season coliform bacteria is 29 CFU/100, while average coliform bacteria is 84.5 CFU/100. The result indicates that both wet season, dry season as well as average coliform count for Kolo sample 5 were above the WHO 2011 and NSDWQ 2007 standards for drinking water quality. This implies that, consumption of water from this particular borehole has serious health negative implications.

Emeya I sample 6, the dry season coliform bacteria is 0 CFU/100 while the wet season coliform bacteria is 0 CFU/100 and average coliform bacteria is 0 CFU/100. The results of Emeyal I sample 6 shows that, the water from this borehole is free from bacteriological contamination therefore it can be used for consumption and other domestic uses. Emeya II sample 7, the dry season coliform bacteria is 0 CFU/100 while the wet season coliform bacteria is 0 CFU/100 and average coliform bacteria is 0 CFU/100. The results of Emeyal II sample 7 shows that, the water from this borehole is free from bacteriological contamination therefore it can be use for consumption and other domestic uses. Emeyal II sample 8, the dry season coliform bacteria is 0 CFU/100 while the wet season coliform bacteria is 26 CFU/100 and average coliform bacteria is 13 CFU/100. The results of Emeyal II sample 8 shows that, the results were above the WHO 2011 and NSDWQ 2007 standards for drinking water quality. This implies that, consumption of water from this particular borehole present a serious health hazards. Elebele sample 9, the dry season coliform bacteria is 0 CFU/100 while the wet season coliform bacteria is 7 CFU/100 and average coliform bacteria is 3.5 CFU/100. The results of Elebele sample 9 shows that, the results were above the WHO 2011 and NSDWQ

2007 standards for drinking water quality. This implies that, consumption of water from this particular borehole indicates serious negative health effects.

The table indicates that, Imiringi sample 10, the dry season coliform bacteria is 0 CFU/100 while the wet season coliform bacteria is 0 CFU/100 and average coliform bacteria is 0 CFU/100. The results of Imiringi sample 10 shows that, the water from this borehole is free from bacteriological contamination therefore it can be used for consumption and other domestic uses. Imiringi sample 11, the dry season coliform bacteria is 0 CFU/100 while the wet season coliform bacteria is 27 CFU/100 and average coliform bacteria is 13.5 CFU/100. The results of Imiringi sample 11 shows that, the results were above the WHO 2012 and NSDWQ 2007 standards for drinking water quality. This implies that, consumption of water from this particular borehole present a serious health hazards. Imiringi sample 12, the dry season coliform bacteria is 108 CFU/100, and wet season coliform bacteria is 0 CFU/100, while average coliform bacteria is 54 CFU/100. The result indicates that both wet season, dry season as well as average coliform count for Imiringi sample 12 were above the WHO 2012 and NSDWQ 2007 standards for drinking water quality. This implies that, consumption of water from this particular borehole has serious health negative implications.

Table: 2 Physico-Chemical Characteristics of Water Quality Parameters in Ogbia Local Government Area

Longitudes	Latitudes	Temp ^oC	Colour	pH	Turbidity	Conductivity	Chloride, Cl^-	Calcium, Ca^{2+}	Nitrate, NO_3	Nitrite, NO_2	TDS	Salinity, NaCI	Total Hardness	Calcium Hardness	Magnesium, Mg^{2+}
6.312889	4.788556	25.5	36.5	7.48	2.00	97.30	5.21	5.3	2.10	7.01	48.65	16.04	21.50	12.50	0.20
6.313111	4.788083	24.8	15	7.42	1.50	103.35	10.5	10.15	1.80	0.04	51.68	17.40	18.00	10.00	0.20
6.322222	4.797889	24.95	16.5	7.59	0.00	155.25	10.35	2.80	1.80	0.04	77.63	20.25	26.00	18.50	0.01
6.375806	4.810444	26.25	0.00	7.29	2.00	199.10	12.87	14.60	1.46	0.02	99.55	21.24	53.00	37.00	0.01
6.376639	4.79775	24.75	2.00	7.56	0.00	97.00	7.63	3.50	2.55	0.05	48.50	12.57	18.00	9.00	0.65
6.354306	4.830806	25.4	0.00	7.07	0.00	76.25	6.50	3.80	0.75	0.02	38.13	14.72	15.50	9.50	0.03
6.352139	4.836833	25.25	45.5	7.25	0.00	96.15	5.57	5.97	1.84	0.15	42.85	9.15	10.50	5.50	0.35
6.354306	4.841833	24.4	5.50	7.21	1.50	148.20	5.57	3.70	1.22	0.02	69.10	9.15	23.50	3.02	0.35
6.346556	4.859111	24.9	41.4	7.37	0.00	158.45	12.91	13.51	1.113	0.02	79.23	46.29	29.00	11.00	0.01
6.345389	4.855667	24.8	0.00	7.44	6.50	106.40	11.85	4.30	1.36	0.05	53.20	19.18	19.00	11.00	0.02
6.372528	4.922083	24.75	2.00	7.46	2.00	88.85	7.32	3.10	2.50	0.04	41.82	49.51	13.00	13.00	0.01
6.371944	4.850944	25.55	0.00	7.31	1.00	682.50	70.50	22.20	3.12	0.04	341.25	116.25	147.00	56.00	0.01
6.381944	4.850964	25.35	0.50	7.55	0.50	107.20	4.50	4.50	1.62	0.01	53.60	17.95	21.50	11.50	0.02
WHO 2012		26.5	Clear	6.5-8.5	5.0	1000	250	100	50	0.1	500	640	150	100	0.2
NSDWQ 2007		AMBIENT	Clear	6.5-8.5	5.0	500	100	50	10	0.1	500	640	100	50	20

Table 3: Contamination Factor and Contamination Index for Groundwater from the Study Areas

Area	Location	Longitudes	Latitudes	Contamination Factor (Cf)					Contamination Index (CI)
				Chloride, Cl-	Calcium, Ca^{2+}	Nitrate, NO_3^-	Nitrite, NO_2^-	Magnesium, Mg^{2+}	
RURAL	Otuoke 1	6.312889	4.788556	0.02084	0.0265	0.042	35.05	0.001333333	35.141
	Otuoke 2	6.313111	4.788083	0.042	0.05075	0.036	0.2	0.001333333	0.330
	Otuoke 3	6.322222	4.797889	0.0414	0.014	0.036	0.2	6.66667E-05	0.291
	Kolo 4	6.375806	4.810444	0.05148	0.073	0.0292	0.1	6.66667E-05	0.254
	Kolo 5	6.376639	4.79775	0.03052	0.0175	0.051	0.25	0.004333333	0.353
	Emeyal (I) 6	6.354306	4.830806	0.026	0.019	0.015	0.1	0.0002	0.160
	Emeyal (II) 7	6.352139	4.836833	0.02228	0.02985	0.0368	0.75	0.002333333	0.841
	Emeyal (II) 8	6.354306	4.841833	0.02228	0.0185	0.0244	0.1	0.002333333	0.168
	Elebele 9	6.346556	4.859111	0.05164	0.06755	0.02226	0.1	6.66667E-05	0.242
	Elebele 10	6.345389	4.855667	0.0474	0.0215	0.0272	0.25	0.000133333	0.346
	Imiringi 11	6.372528	4.922083	0.02928	0.0155	0.05	0.2	6.66667E-05	0.295
	Imiringi 12	6.371944	4.850944	0.282	0.111	0.0624	0.2	6.66667E-05	0.655
	Imiringi 13	6.381944	4.850964	0.018	0.0225	0.0324	0.05	0.000133333	0.123

Results in table 3 indicate that, Otuoke sample 1 shows that contamination factor for Chloride 0.02084 mg/l, Calcium 0.0265 mg/l, Nitrate 0.042 mg/l, Nitrite 35.05 mg/l, Magnesium 0.001333333 mg/l, while the Contamination Index is 35.141. Otuoke sample 2 indicates that contamination factor for Chloride 0.042 mg/l, Calcium 0.05075 mg/l, Nitrate 0.036 mg/l, Nitrite 0.2 mg/l, Magnesium 0.001333333 mg/l, while the Contamination Index is 0.330. Otuoke sample 3 shows that contamination factor for Chloride 0.0414 mg/l, Calcium 0.014 mg/l, Nitrate 0.036 mg/l, Nitrite 0.2 mg/l, Magnesium 6.66667E-05 mg/l, while the Contamination Index is 0.291.

Kolo sample 4 shows that contamination factor for Chloride 0.05148 mg/l, Calcium 0.073 mg/l, Nitrate 0.0292 mg/l, Nitrite 0.1 mg/l, Magnesium 6.66667E-05 mg/l, while the Contamination Index is 0.254. Kolo sample 5 indicates that Contamination factor for

Chloride 0.03052 mg/l, Calcium 0.0175 mg/l, Nitrate 0.051 mg/l, Nitrite 0.25 mg/l, Magnesium 0.004333333 mg/l, while the Contamination Index is 0.353.

Emeyal (I) sample 6 shows that contamination factor for Chloride 0.026 mg/l, Calcium 0.019 mg/l, Nitrate 0.015 mg/l, Nitrite 0.1 mg/l, Magnesium 0.0002 mg/l, while the Contamination Index is 0.160. Emeyal (II) sample 7 indicates that contamination factor for Chloride 0.02228 mg/l, Calcium 0.02985 mg/l, Nitrate 0.0368 mg/l, Nitrite 0.75 mg/l, Magnesium 0.002333333 mg/l, while the Contamination Index is 0.841. Emeya (III) sample 8 shows that contamination factor for Chloride 0.02228 mg/l, Calcium 0.0185 mg/l, Nitrate 0.0244 mg/l, Nitrite 0.1 mg/l, Magnesium 0.002333333 mg/l, while the Contamination Index is 0.168.

Elebele sample 9 shows that contamination factor for Chloride 0.05164 mg/l, Calcium 0.06755 mg/l, Nitrate 0.02226 mg/l, Nitrite 0.1 mg/l, Magnesium 6.66667E-05 mg/l, while the Contamination Index is 0.242. Elebele sample 10 indicates that contamination factor for Chloride 0.0474 mg/l, Calcium 0.0215 mg/l, Nitrate 0.0272 mg/l, Nitrite 0.25 mg/l, Magnesium 0.000133333 mg/l, while the Contamination Index is 0.346.

Imiringi sample 11 shows that contamination factor for Chloride 0.02928 mg/l, Calcium 0.0155 mg/l, Nitrate 0.05 mg/l, Nitrite 0.2 mg/l, Magnesium 6.66667E-05 mg/l, while the Contamination Index is 0.295. Imiringi sample 12 indicates that contamination factor for Chloride 0.282 mg/l, Calcium 0.111 mg/l, Nitrate 0.0624 mg/l, Nitrite 0.2 mg/l, Magnesium 6.66667E-05 mg/l, while the Contamination Index is 0.655. Imiringi sample 13 shows that contamination factor for Chloride 0.018 mg/l, Calcium 0.0225 mg/l, Nitrate 0.0324 mg/l, Nitrite 0.05 mg/l, Magnesium 0.000133333 mg/l, while the Contamination Index is 0.123.

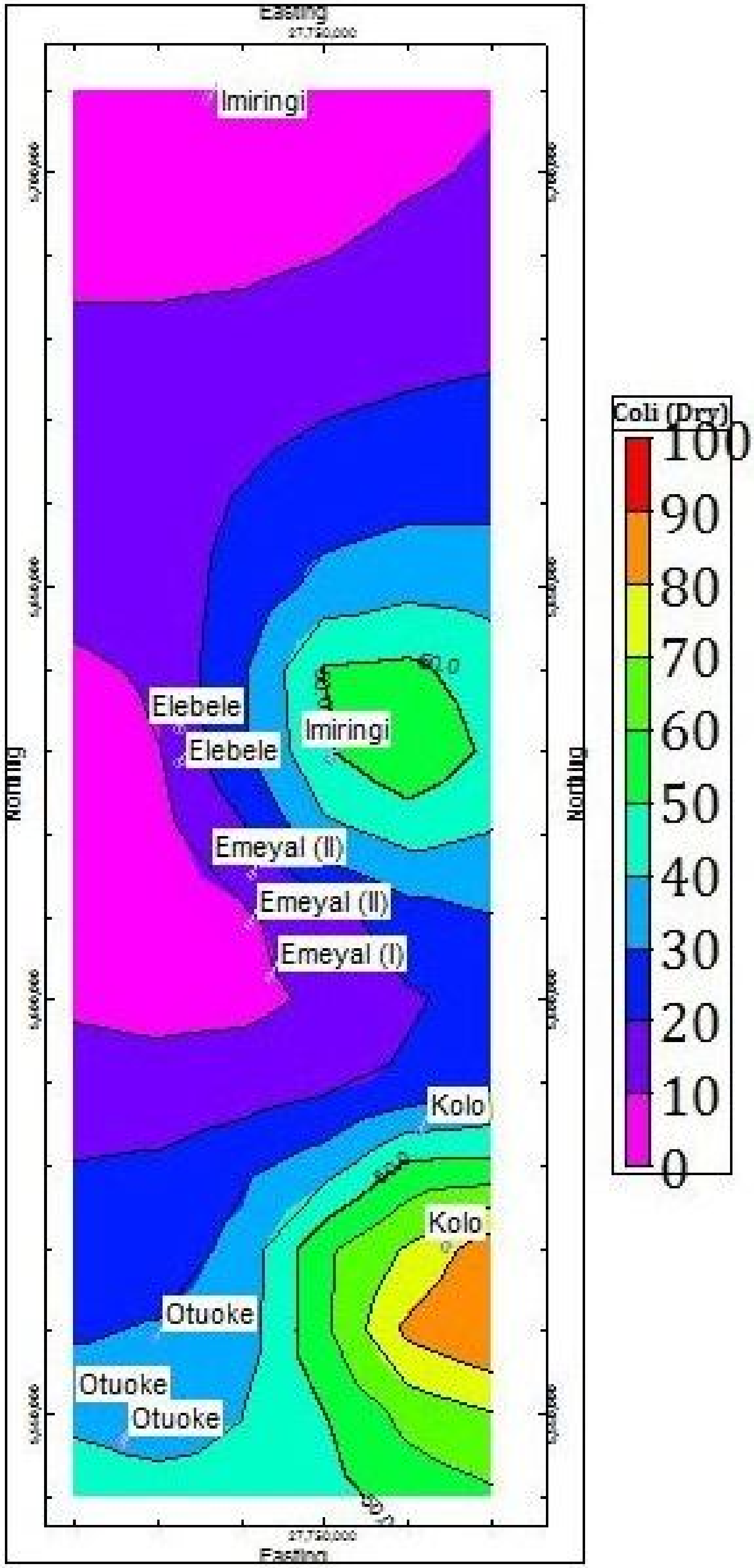

Fig. 2: Coliform Concentration in the Study Area (Dry Season)

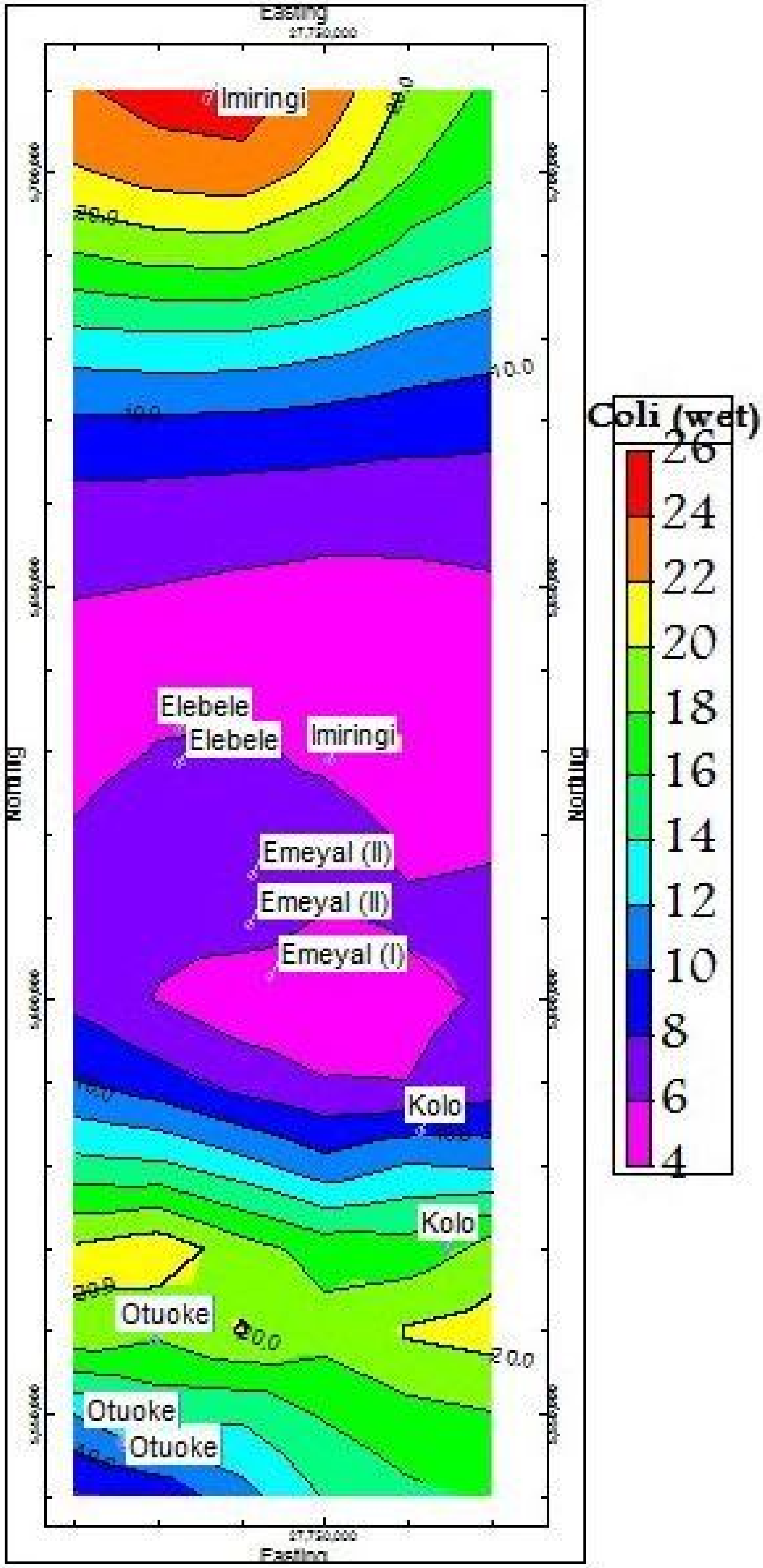

Fig. 3: Coliform Concentration in the Study Area (Wet Season)

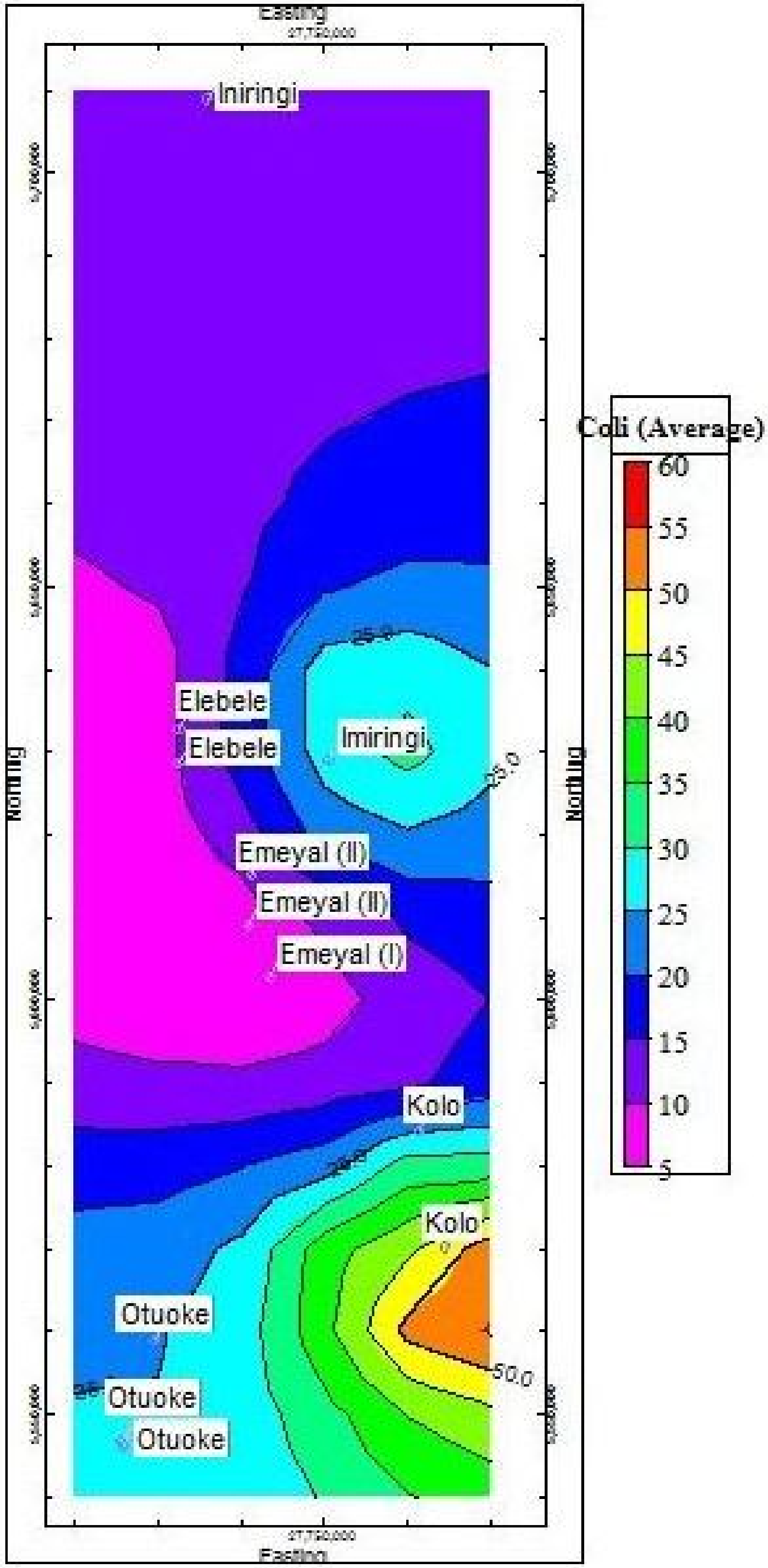

Fig. 4: Average Coliform Concentration in the Study Area (Wet & Dry Season)

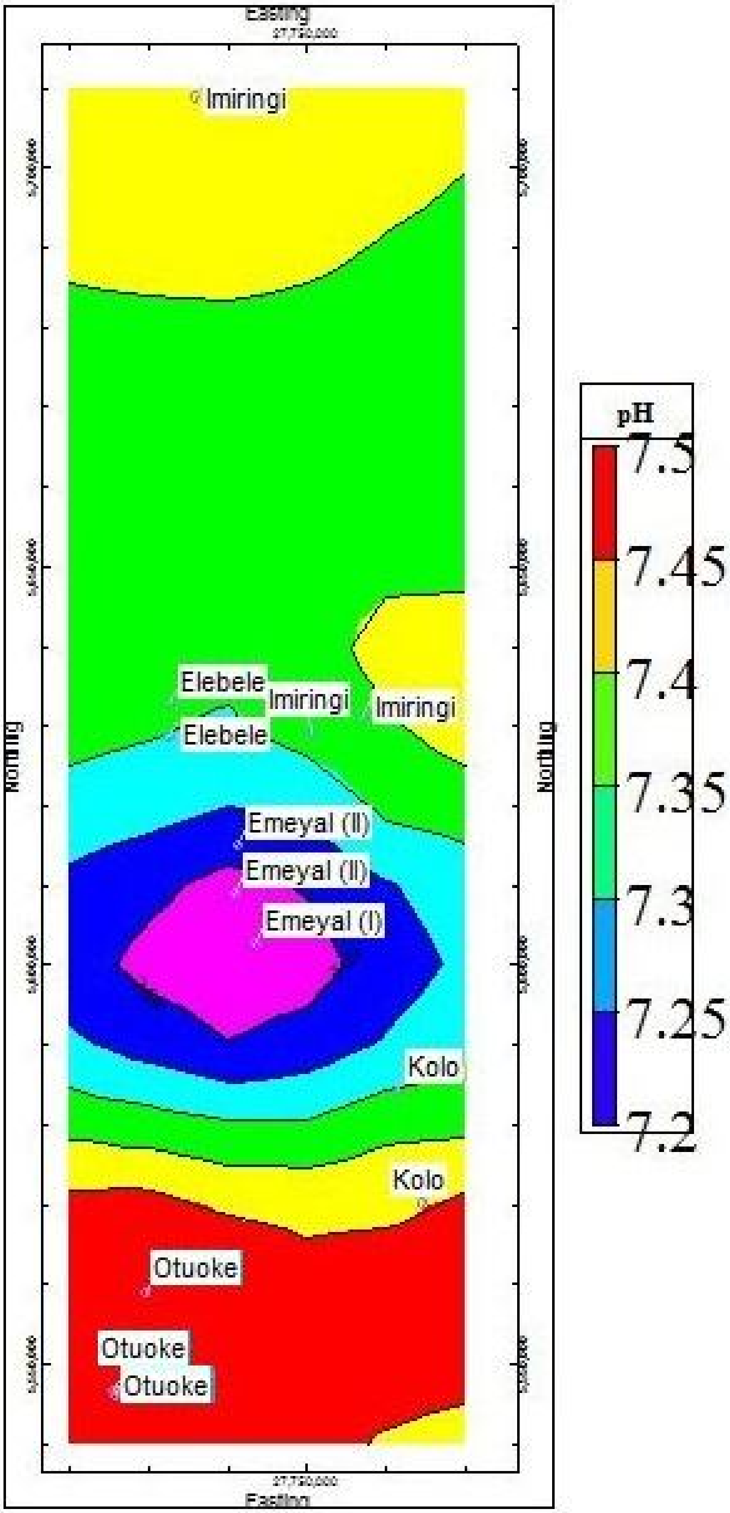

Fig. 5: pH Concentration in the Study Area

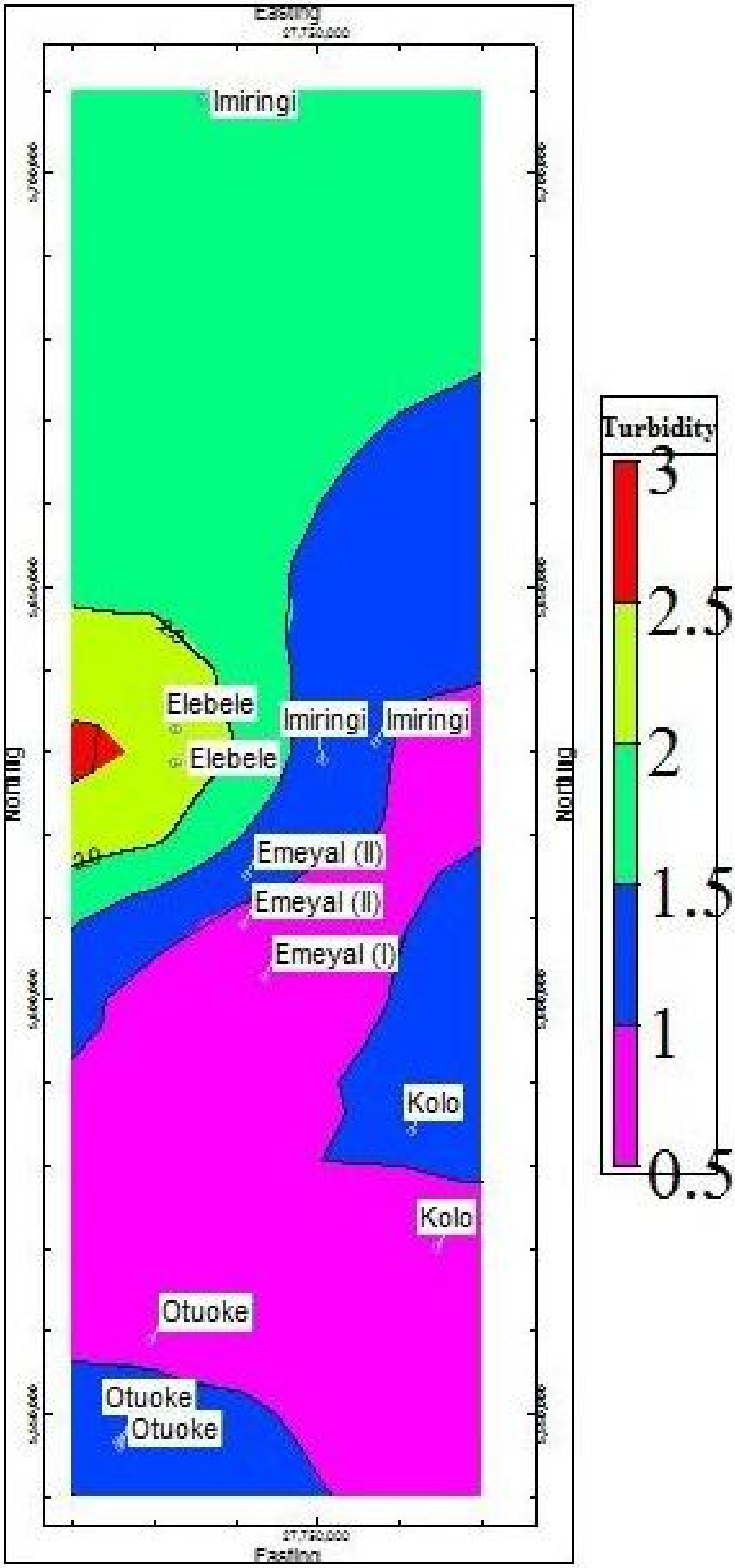

Fig. 6: Turbidity Concentration in the Study Area

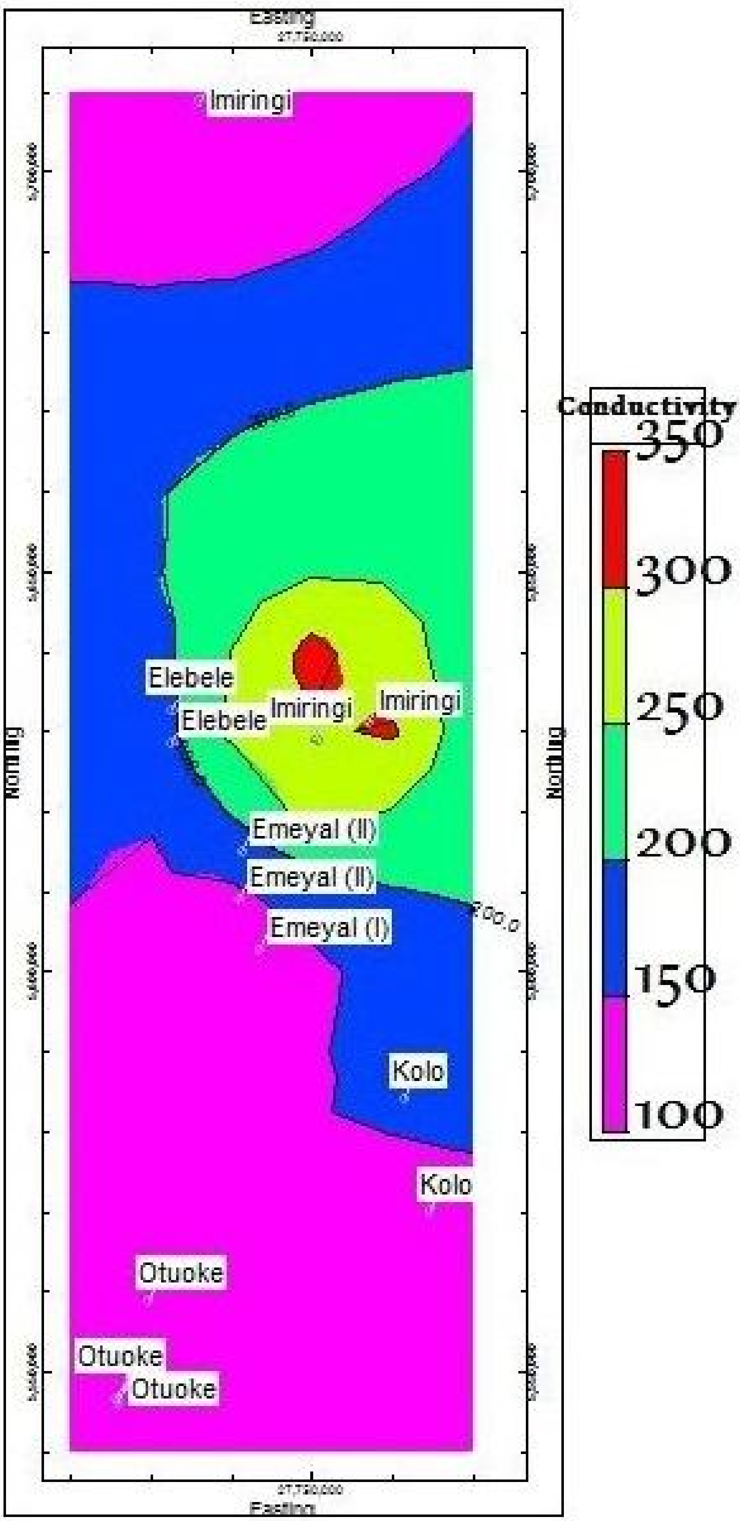

Fig. 7: Conductivity Concentration in the Study Area

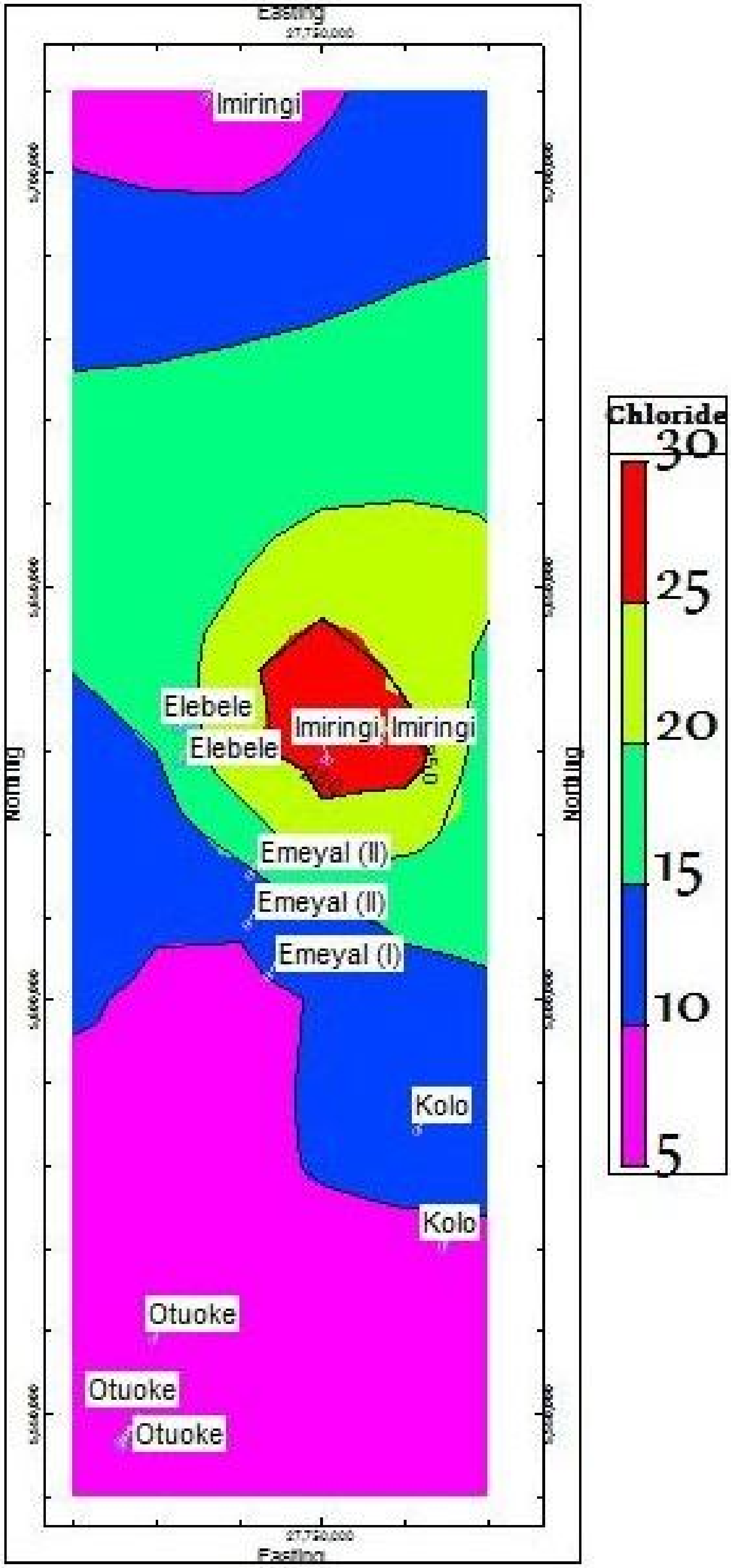

Fig. 8: Turbidity Concentration in the Study Area

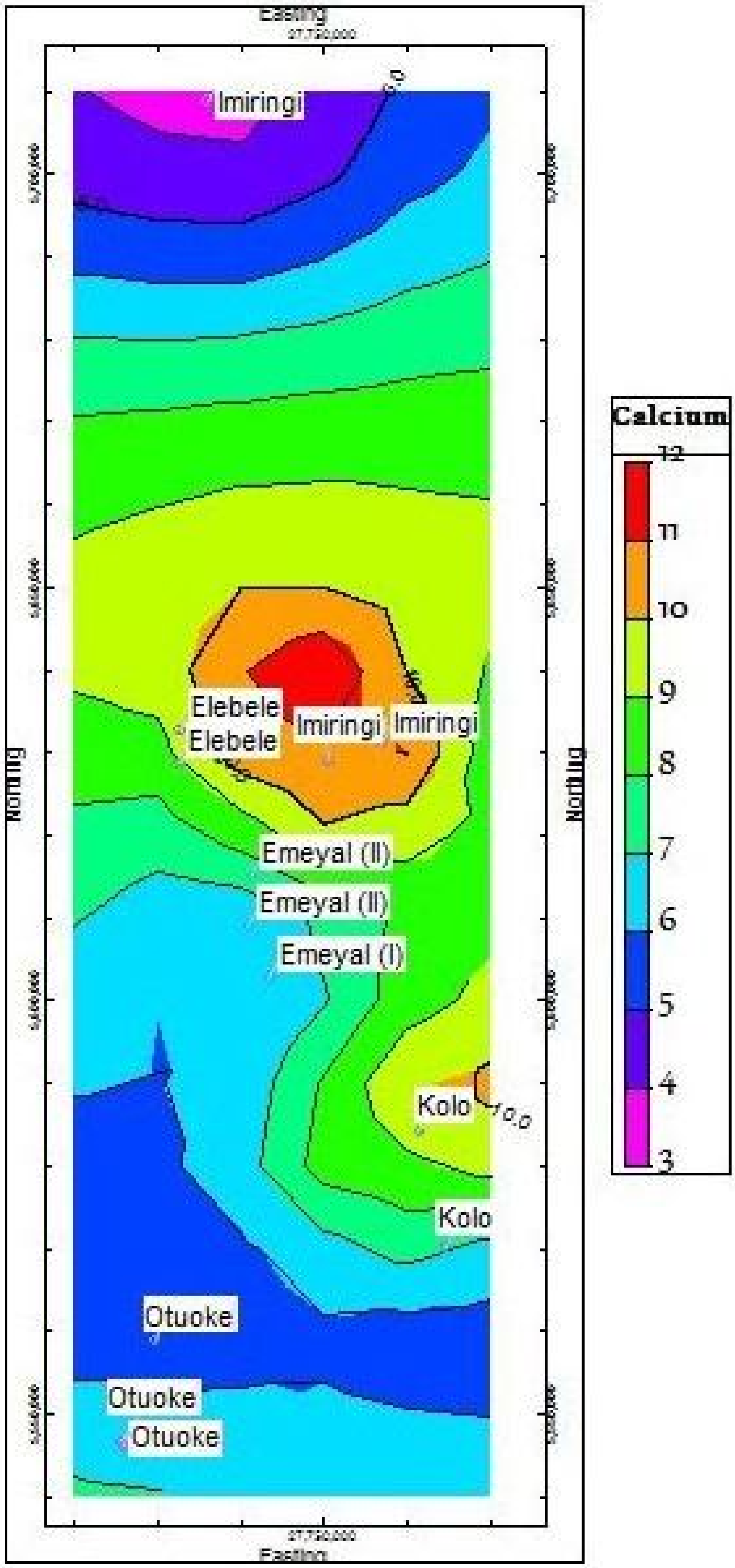

Fig. 9: Calcium Concentration in the Study Area

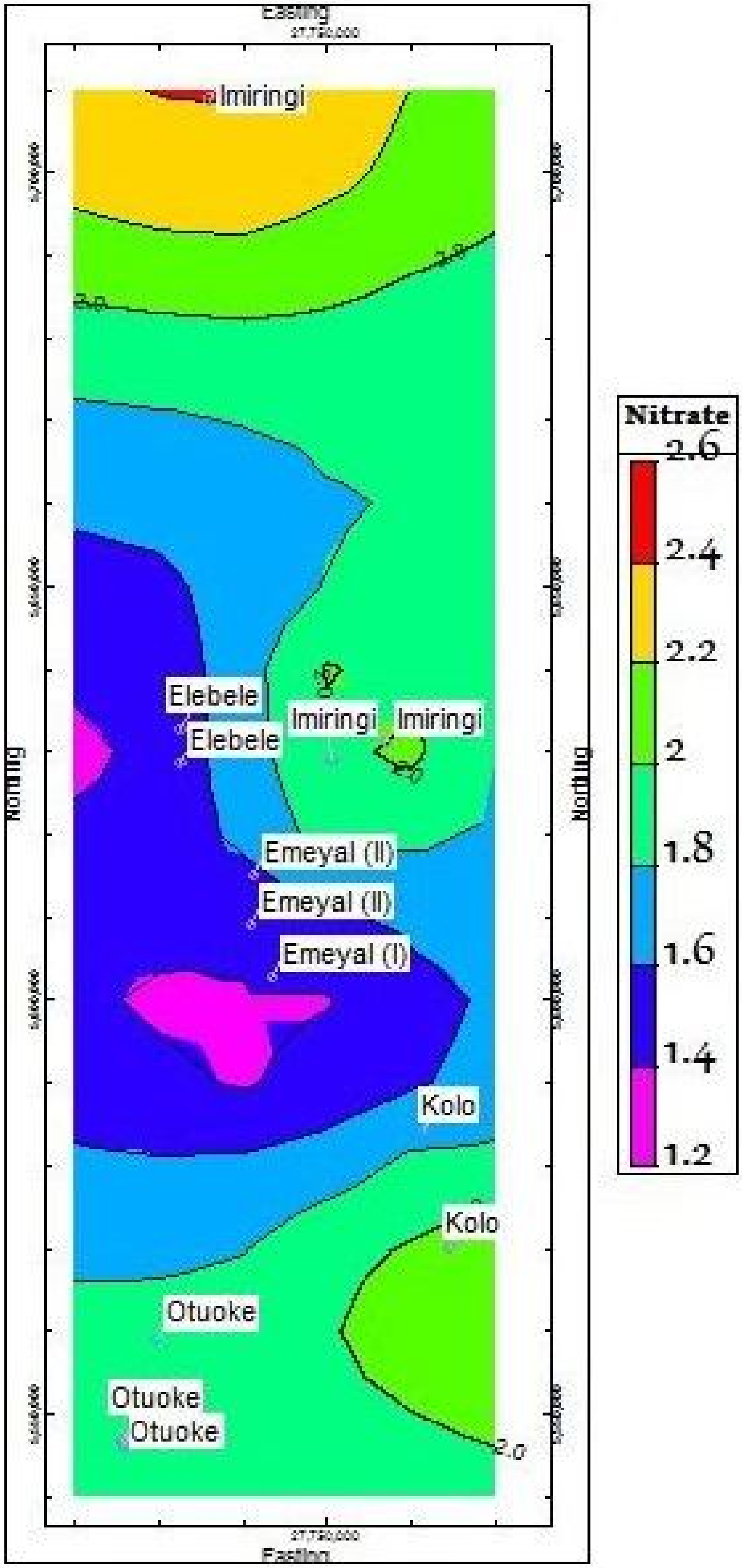

Fig. 10: Nitrate Concentration in the Study Area

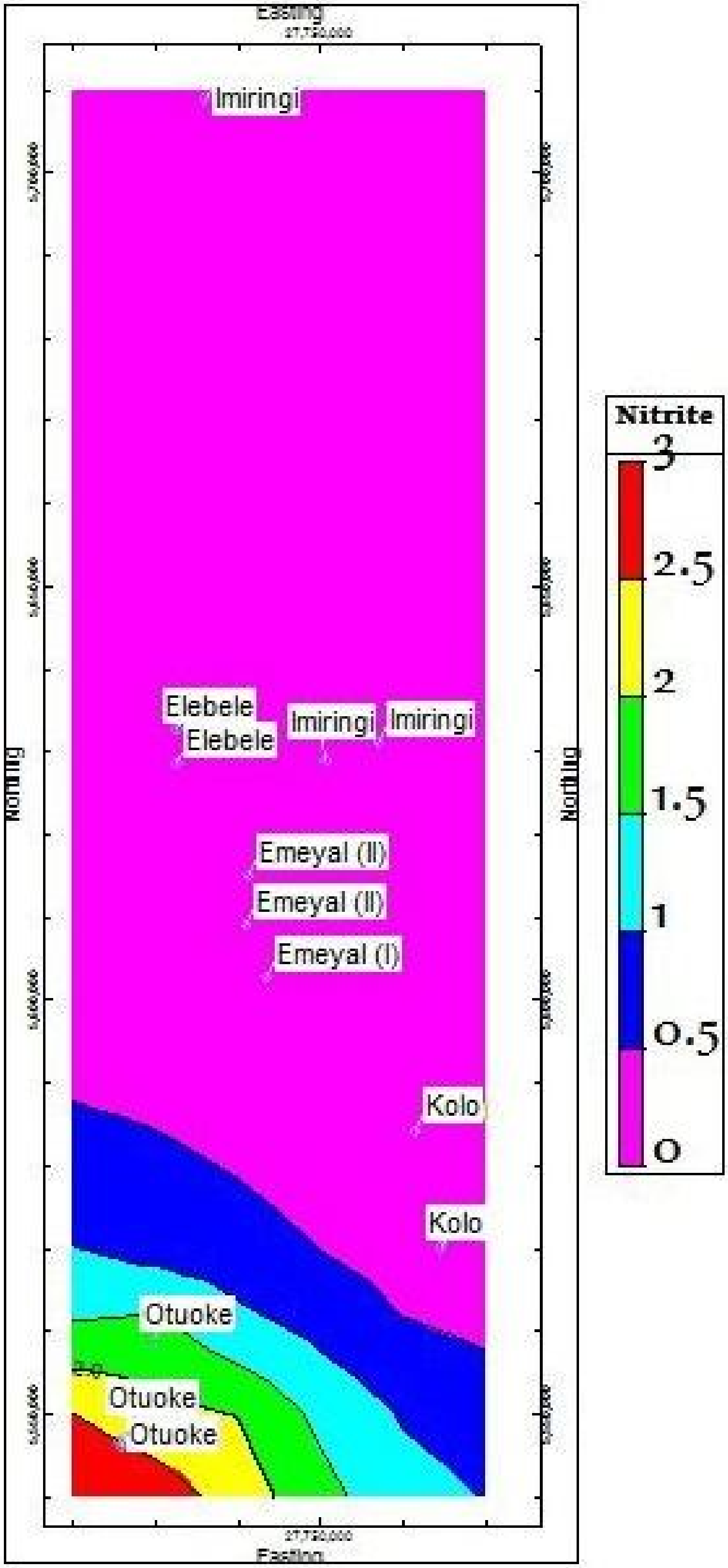

Fig. 11: Nitrite Concentration in the Study Area

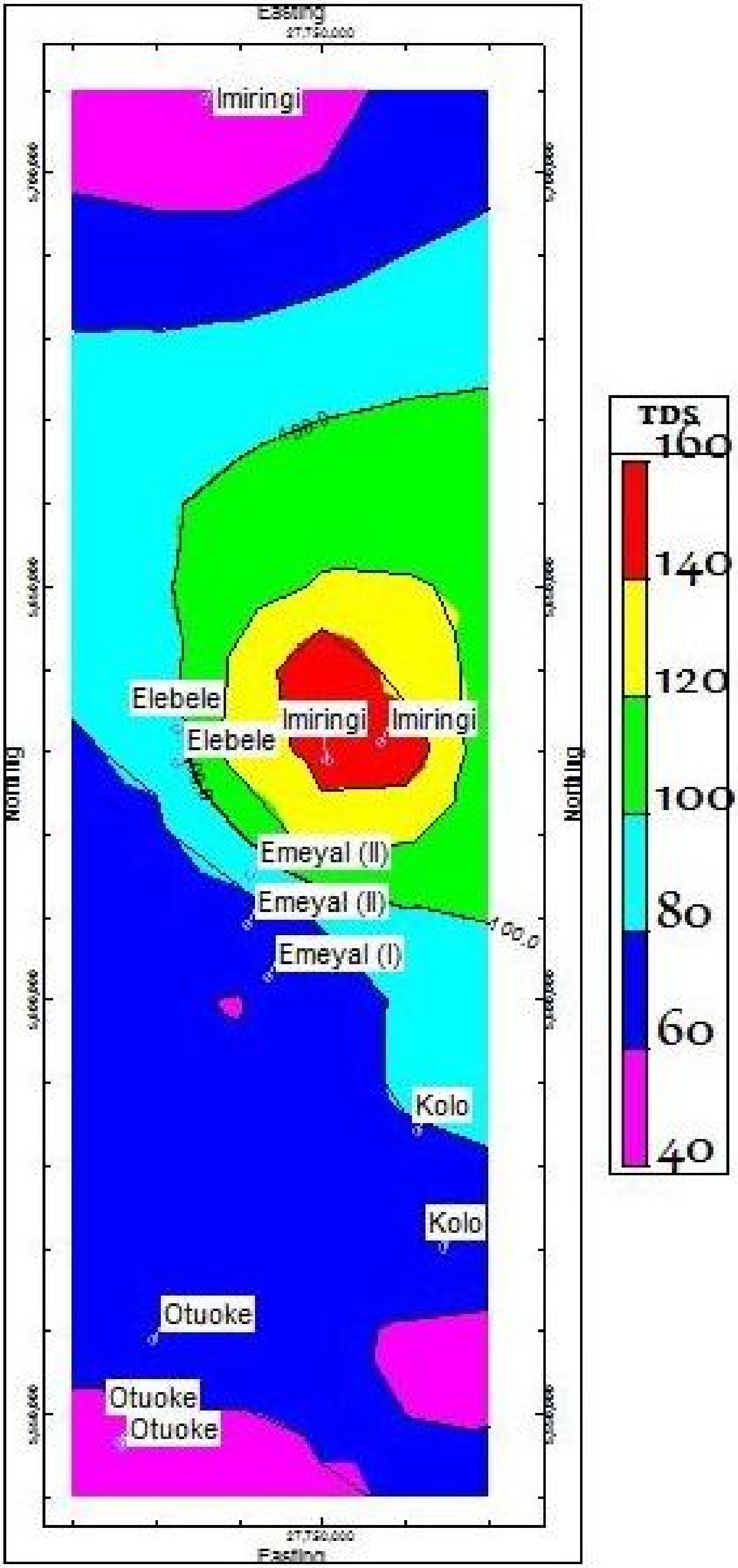

Fig. 12: TDS Concentration in the Study Area

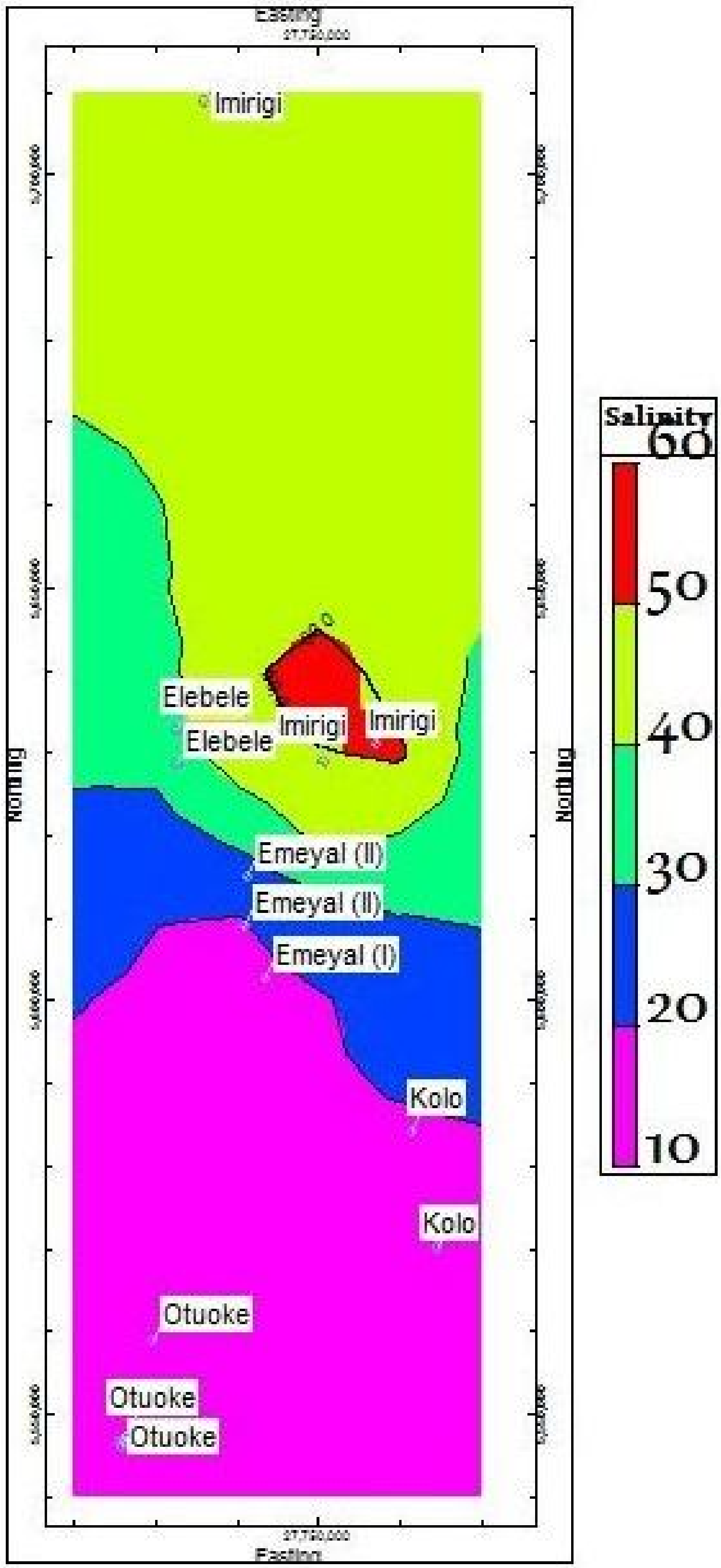

Fig. 13: Salinity Concentration in the Study Area

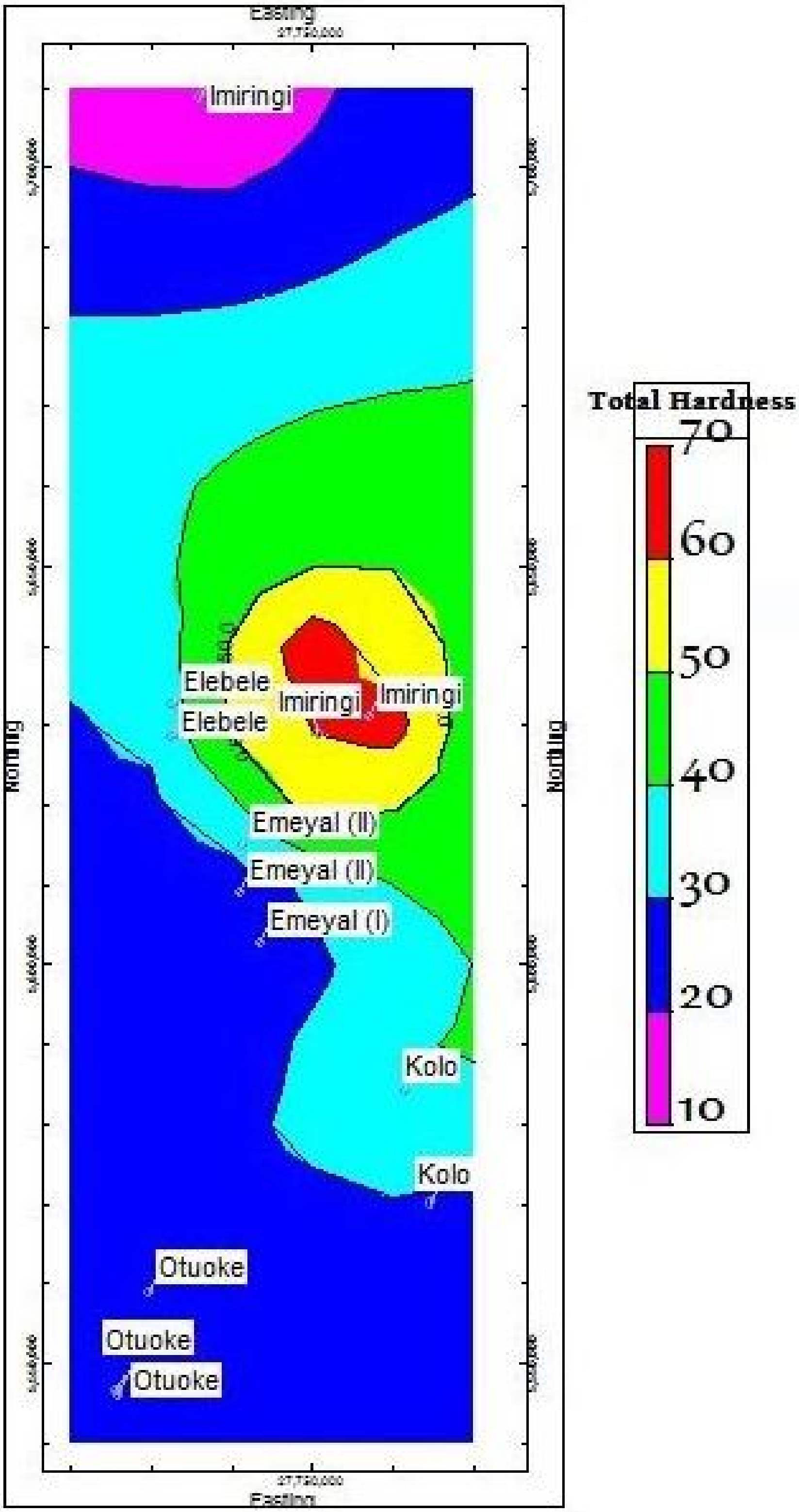

Fig. 14: Total Hardness Concentration in the Study Area

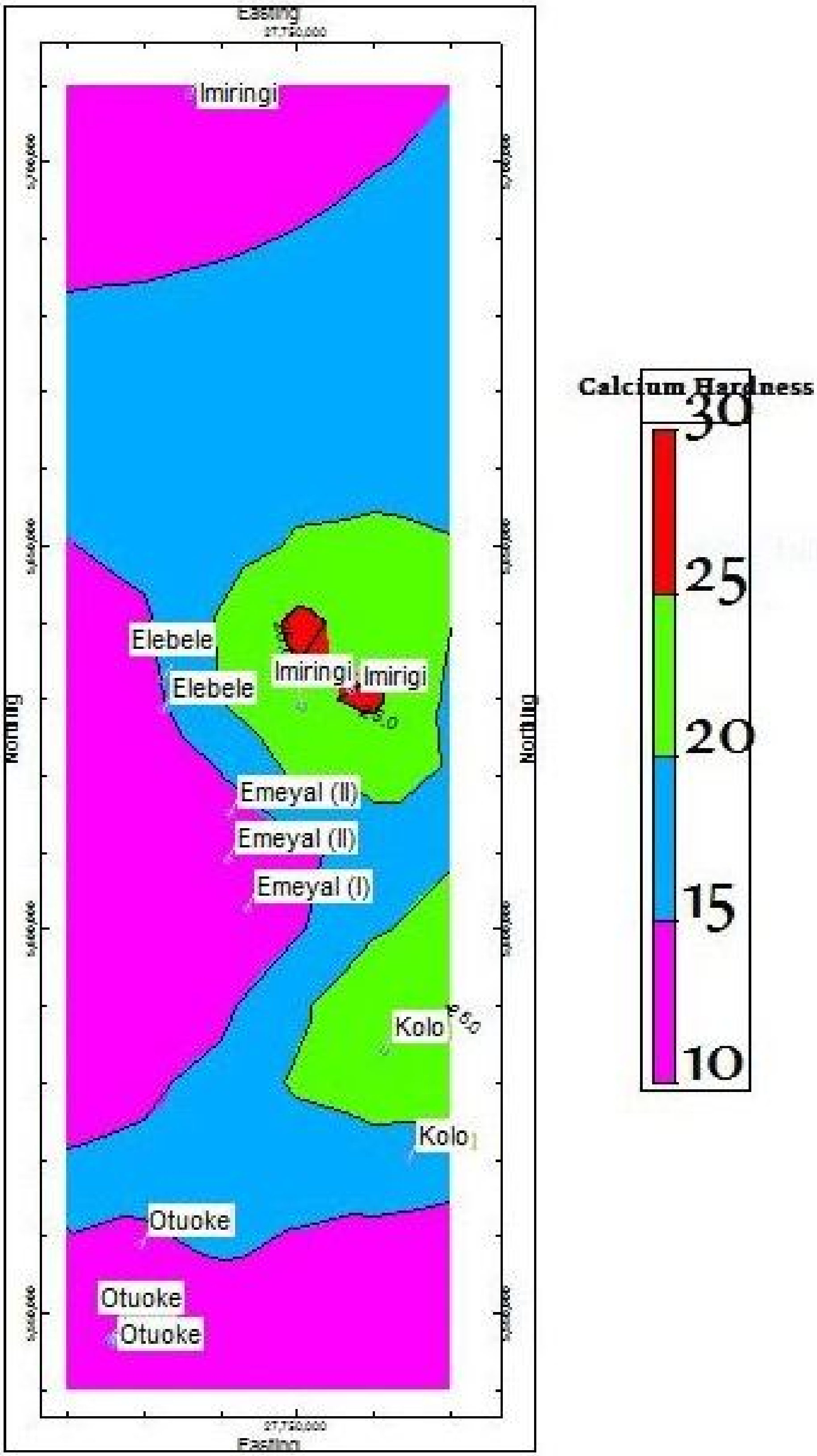

Fig.15: Calcium Hardness Concentration in the Study Area

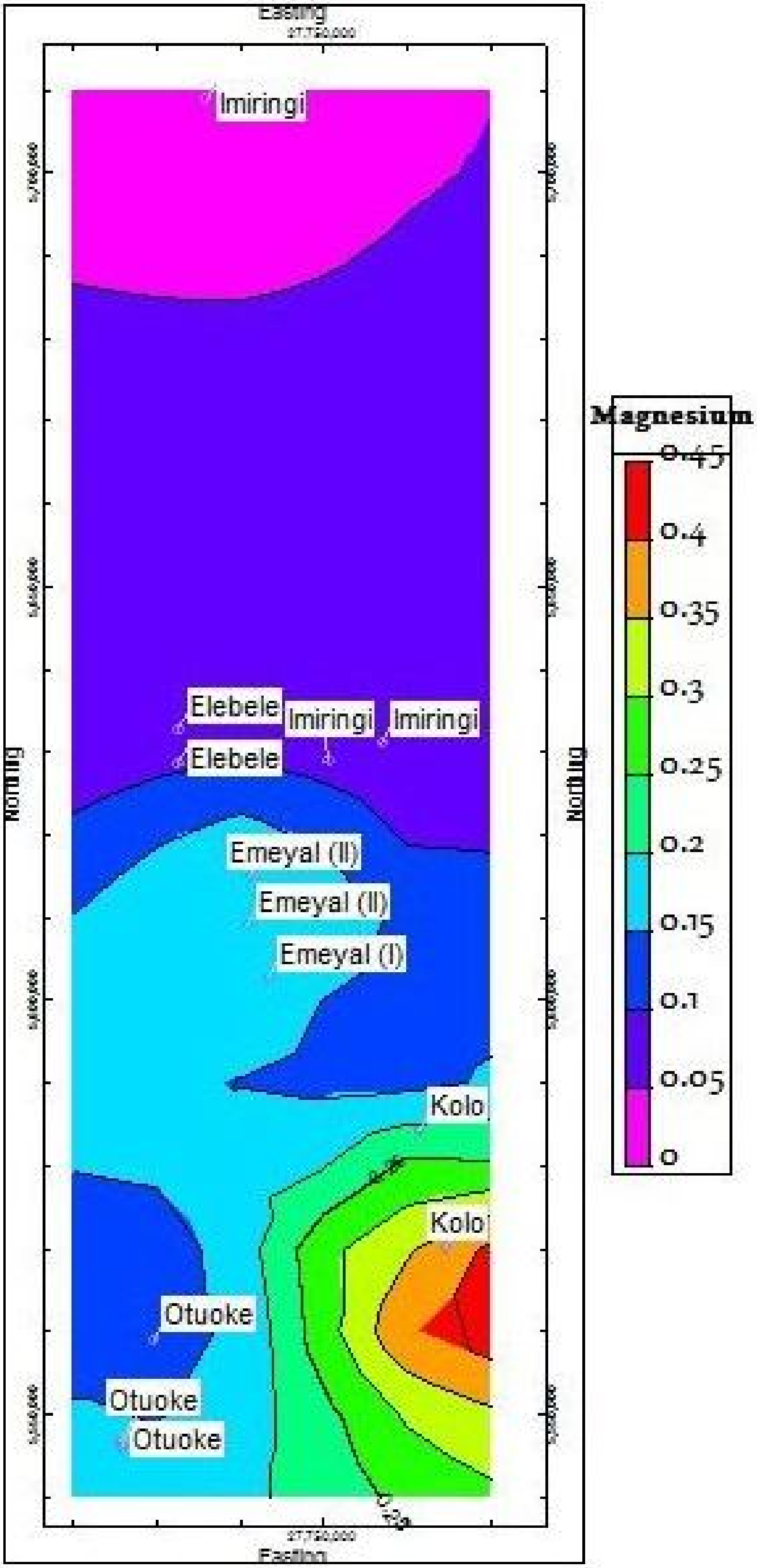

Fig. 16: Magnesium Concentration in the Study Area

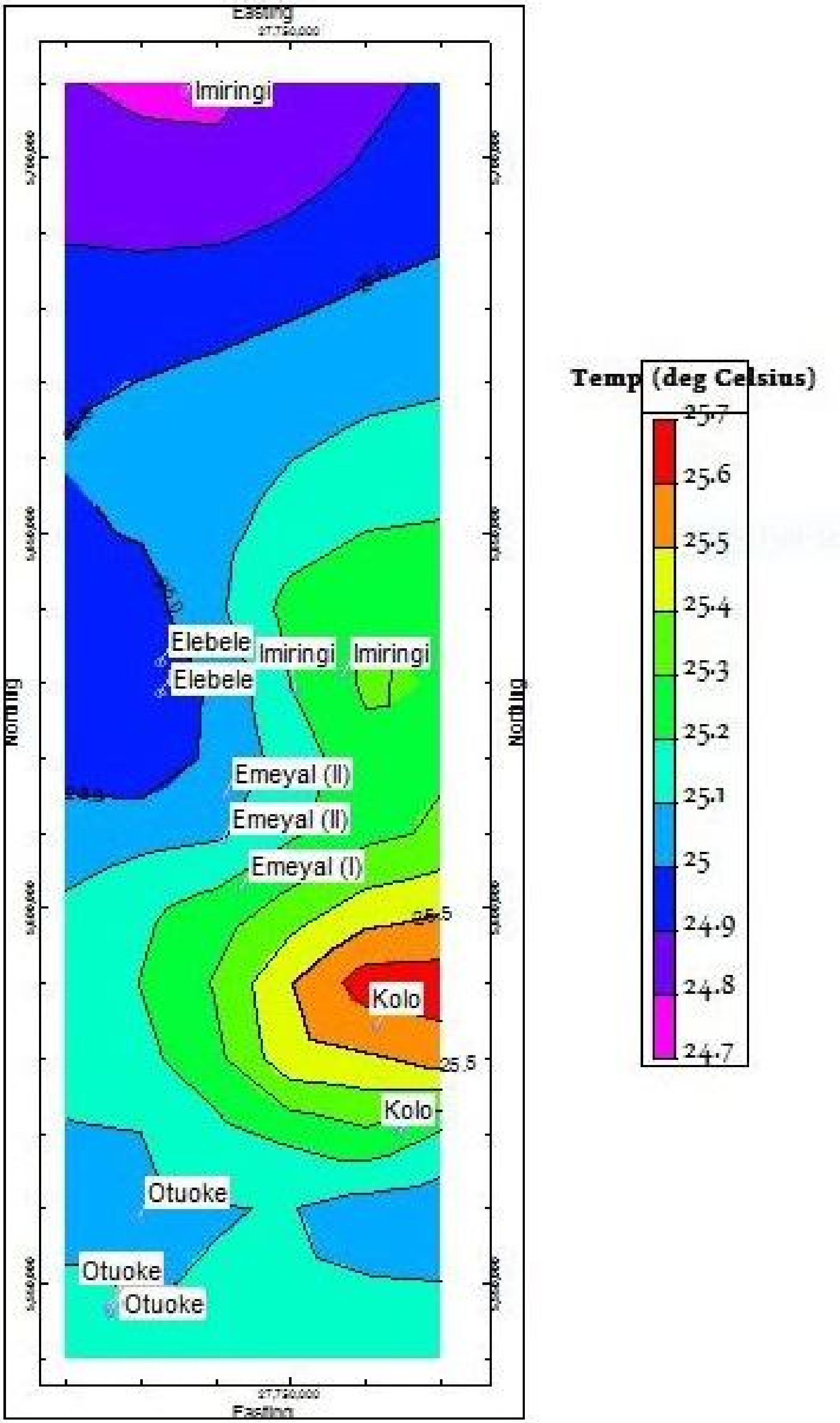

Fig. 17: Temp (Deg Celsius) Concentration in the Study Area

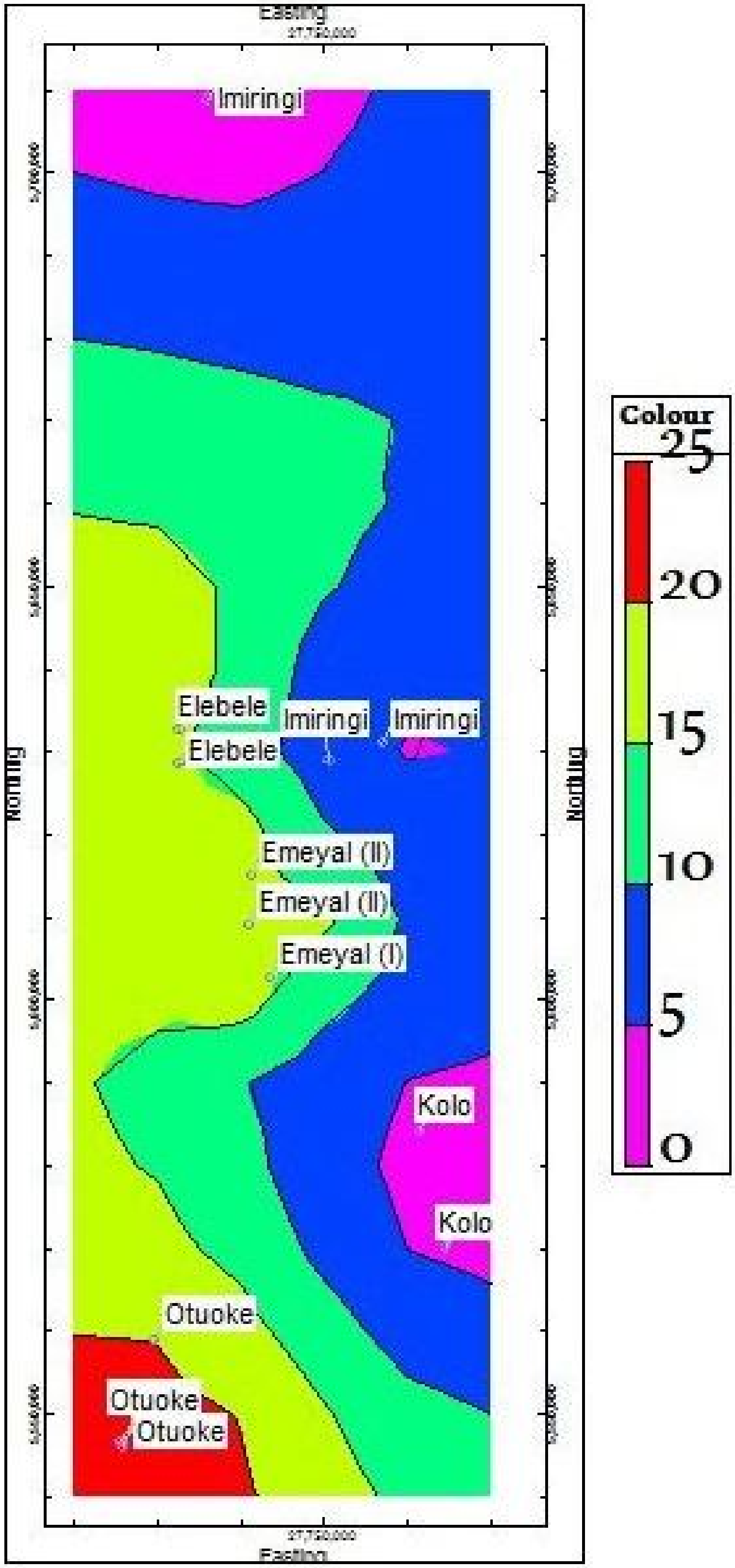

Fig. 18: Colour Concentration in the Study Area

Conclusion

Water is required for difference purposes in our society, its importance cannot be over-emphasized. Despite the significant role water place in our society, the greatest problem is accessing the good quality water. Water of a good quality is a major problem in Nigeria especially in the Niger Delta Region were oil exploration and exploitation has resulted to several crude oil spillages thereby polluting the ground and surface water. The findings of the study revealed that, most of the boreholes in the study area were either polluted by heavy metals, physico-chemical and bacteriological parameters. This has serious negative health implications on the users of these boreholes water. This therefore, requires various interventionist measures to ameliorate the effects of consuming this water source.

Recommendations

Arising from the findings above, the following are the recommendations of the study:

(1) Most of the boreholes in the study area are either contaminated by bacteriological and some physico-chemical parameters. This require proper treatment of water from these boreholes to meet the WHO and NSDWQ standard limits.

(2) Boreholes should be located away from septic tanks to remove the impact of bacteriological contamination.

(3) Borehole should be located some distance away from dump-sites, this will help in reducing the concentration of heavy metals and coliform bacteria in the groundwater.

(4) Boreholes should be instantly monitored from time to time, this will help to ascertain the quality of groundwater from each borehole. The need arises as a result of the fact that groundwater flow is not static but dynamic, a borehole that is free from pollution today does not mean that it will be the same tomorrow.

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