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Effects of Sewage Effluent on Underground Water Quality in Enugu Metropolis

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***Abstract**: The study is concerned with determining the effects of sewage effluent on underground water quality in Enugu metropolis. Due to improper and neglected sewage systems and other domestic activities such as domestic sewage, agricultural run-off water containing chemical pesticides and fertilizer residues, etc. had led to groundwater getting polluted. Samples were obtained from three different locations: Gariki, Ikem street Abakpa and Liberty Abakpa, all in Enugu. Two samples each were obtained from these locations, a sample from a contaminated source and the other from an uncontaminated source, making it a total of six (6) samples. Various criteria were considered for the selection of bore well. A physio-chemical test was conducted on all six samples. The guidelines of the World Health Organization for drinking water and BIS, Indian standard served as a guide in comparing the results obtained from the samples. From the analysis, it was observed that the contaminated water samples obtained from Abakpa and Gariki precisely are acidic, which could pose health risk, has low conductivity, turbidity is high, alkalinity is low and low total dissolved solids. From this research it can be concluded that the potential source of groundwater pollution is the septic tank in an urban settlement, since most of the contaminated water samples were obtained from areas with improperly maintained sewage system and at a distance too close to the water source. It is recommended that it is paramount to make available safe distance from the septic tank to the water sources. Also, proper management of sewage disposal and treatment systems can also be an ideal solution to this problem. To reduce the pollution of ground water, decentralized sewage treatment is also necessary.*

***Keywords**: Groundwater, Physio-chemical, Effluent, Borehole, septic tank, decentralized.*

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I. Introduction

Groundwater is a major part of the Earth's hydrological cycle. The sun energy drives this cycle and moves water from the oceans and transports it across the atmosphere back to the oceans through various routes. Precipitation falling on the land surface represents the source of fresh water. About one-fourth of the quantity of precipitation infiltrates the soil and recharges local aquifers and the sediments. According to Central Ground Water Board estimates, it accounts for nearly 80 per cent of the rural domestic water needs, and 50 per cent of the urban water needs in Nigeria, depends on groundwater. Groundwater is used for different purposes such as domestic purpose, industrial and agricultural purpose. Due to the improper impact of human activities, groundwater always gets polluted from different sources such as domestic sewage, industrial effluents, radioactive waste materials, agricultural run-off water containing chemical pesticides and fertilizer residues, hazardous and biomedical waste disposal, leachates percolating from landfills, oil spills and accidental leakage of oil. The quality of groundwater depends on various chemical constituents and their concentration, which are mostly derived from the geological data of the particular region through groundwater flows. Industrial waste and the municipal solid waste have come forth as one of the leading causes of pollution of surface water and groundwater. In most parts of the country, available groundwater is rendered non-potable because of the high Chlorides, Nitrates, Hardness and TDS. The situation gets worsened during the summer season due to water scarcity. Contamination of water resources available for household and drinking purposes with heavy elements, metal ions and harmful microorganisms is one of the serious major health problems. As a result, huge amount of money is spent for chemical treatment of contaminated groundwater to make it potable. Thus there is a need to look for some useful indicators, both chemical and physical, which can be used to monitor both drinking water operation and performance. Water is an important resource for the survival of any living thing. Availability of the water and quality of water is very important. Surface water and groundwater are the two forms of water.

Groundwater present in permeable geological formation is known as aquifer. Groundwater is a necessary and very important component of our life support system. The groundwater resources are being utilized for drinking, irrigation and industrial purposes (Rao, et al., 2004, Reddy, K. M. et al., 2003). There is growing concern on decreasing quality of groundwater due to various natural and man-made activities. Groundwater is contaminated in city mainly due to sewage, industrial waste and in the rural areas' groundwater is contaminated due to sewage, industrial waste and application of chemical fertilizers in the agricultural fields. The quality of groundwater has undergone a change to an extent that the groundwater is not fit for drinking purpose. Increase in overall salinity of the groundwater and presence of high concentrations of fluoride, nitrate, iron, arsenic, total hardness and few toxic metal ions have been noticed in large areas in several states of India (Gopal, R., et al., 1983). Groundwater contains wide varieties of dissolved inorganic chemical constituents in different concentrations due to chemical and biochemical interactions between water and the geological materials through which it flows and to a lesser extent because of contribution from the atmosphere and surface water bodies (Patil, S., 2000)

Increase of waste production is correlated with economical and demographical development. While life improvement expected, such development also leads to negative effects on the environment and economy of many countries. Demographical development and intensification of the economic activities in the country are accompanied by an increase in solid waste production (Kherici N, 1993; Djabri L, 1996; Debieche et al, 2003). The considered zone, that is expected to be the third industrial node of the country, has experienced an intensification of demography (higher than 800000 inhabitants) (RGPH, 2001) and economy (higher than 150 industrial units). Environmental problems such as air and water pollution could seriously set back these economical and urban developments. Indeed, several hundreds of tons/day of solid and liquid wastes are dumped in environment lacking any treatment. This uncontrolled dumping has negative effects that are clearly identified such as nauseous smells, smoke generation, water and soil pollution (Debieche et al, 2003, Hani A, 2003). The industrial effluents contain appreciable amounts of both inorganic and organic chemicals and their bye-product. Most industries are in small scale sector and are having any sewer lines. Even today most of them don't have proper waste water treatment plants and they discharge industrial effluents in unlined channels and streams and thereby causing enormous contamination of air, water and soil. The application of sewage sludge and effluents on agricultural soils is increasingly receiving attention (Harivandi, 1982; jiries, 2001; Arar, 1991). This has become an important routine of urban and industrial wastes disposal programmes with substantial ecological and recreational benefits (Day et al., 1972; Gorden et al., 1975; D'Itri et al., 1981; FAO, 1992; Strauss, 2000). Waste water is a complex resource, with both advantages and inconveniences for its use. To the extent that waste water and its nutrient contents can be used for crop production, it provides significant benefits to the farming communities and society in general. However, waste water can also impose negative impacts on communities and on ecosystems. The widespread use of adequate finances for treatment is likely to cause an increase in the incidence of waste water-borne diseases as well as more rapid degradation of the environment. Along with hazardous concentration of soluble salts and heavy metals, all the sewage waters do contain plant nutrients and organic matter (Ghafoor et al., 1995). In humans, the intake of poor quality drinking water has been implicated in the incidence of motor neuron disease (Smith et al., 1996), reproductive disorders and cardiovascular disease (Clayton, 1976). The monitoring of drinking water quality has been widely practiced and reported (Tiwana et al., 1992).

Contamination of ground water depends on various factors; the rock units that form the lithology of the subsurface, the porosity, and the permeability of the subsurface within the given environment (Nathanson JA). Septic refers to the anaerobic bacteria environment that develops in the tank which decomposes the waste discharged into the tank. All over the world, waste and particularly sewage disposal are deposited in the ground. In Africa pits are dug and slabs built over it in a small house a little removed from the main house, defecation is done there until it is filled and made. ln this pattern the waste is directly in contact with the ground and pollution rate is high. But modern life introduced septic tanks (Deborde D.C. et al., 1998 and EL Attar L, et al., 1982) whereby chambers are built with cement walls. These walls are subject to degradation with time. Chemical wastes, biological or organic wastes in form of feaces and other contaminants fill these tanks. These contents stay there for a long time. They decompose and also reduce the strength of the cement walls. This degradation deteriorates into leakage of the septic tanks. The leachets infiltrates into the aquifer system and the surrounding environment and thereby causing groundwater pollution and subsequently lowering the ground water quality. Another consequence of this is reduction in strength of the rock units around the septic tanks. In this regard the effects of leaking septic tanks on groundwater quality in Enugu Municipal is necessary since it is sitting on a highly porous and permeable geologic setting with the highest transmissivity coefficient. It is necessary to investigate these effects by employing some geo-chemical analysis, carrying out vertical electrical sounding to ascertain the geo-electric sections of the rock units (Kaplan

B.O. 1987 & Krumbein WC, et al., 1963). This will give insight of the effects of sewage effluents in underground quality within the Enugu Municipal which is the purpose of this study.

Study Area

The study area is in Enugu. Enugu is the capital of Enugu state in Nigeria. It is located in southeastern Nigeria. The city had a population of 722,664 according to the 2006 Nigeria census. It is located within latitude $6^o27^I10^{II}$N and longitude $7^o30^I40^{II}$E. It covers an estimated area of 556km^2 ("Enugu State population" City population).

The study area (Enugu municipal, Eastern Nigeria)

Figure 1. Map of Nigeria showing the city, Enugu. (Wikipedia)

The name Enugu was obtained from the two igbo words Énú Úgwú meaning "hilltop" denoting the city's hilly geography. The city was named after Enugwu Ngwo, under which coal was found. Enugu is located in the Cross River basin (Udo, p.89) and the Benue trough and has the best developed coal in this area (Wright, J.B. 1985). Other geological features in Enugu include the Nike Lake near which the Nike Lake Hotel has been built (Williams .p.196). The Ekulu, Asata, Ogbete, Aria, Idaw and Nyaba rivers are the six largest rivers located in the city (Ofomata, G.E.K; et al, 1994). The Ekulu River is the largest body of water in Enugu Urban (Adalkpoh, E.O; et al) and its reservoir contributes to part of the city's domestic water supply (Egboka, B.C.; et al, 1985). Enugu is located in tropical rainforest zone with a derived savannah (Sanni, L.O. 2007, Reifsnyder, et al 1989). The city has a tropical savanna climate. Enugu's climate is humid and this humidity is at its highest between March and November (Reifsnyder, et al 1989). For the whole of Enugu state, the mean daily temperature is 26.7^{o}c (80.1^{o}F) (Sanni, L.O., 2007). Enugu also includes Abakpa, Gariki etc. The samples analysed in this work was obtained from Abakpa (Ikem street and Liberty) and Gariki.

Investigation was conducted to analyze various characteristics of water samples located close to septic tank and any untreated effluents released from domestic discharges and to study their impact on groundwater quality.

II. Materials and Methods

This study aims at determining the effect of sewage effluent on groundwater quality. The objective is to determine the characteristics of water from borehole (wells) very much at risk of contamination from sewage and to ascertain the characteristics of water from borehole in the same vicinity not located near sewage.

Water samples analyses

Samples were collected from each zones from a Bore well representing that area. Bore wells which are not in use or have been neglected, are not used for sampling. For collection of samples, pre-cleaned plastic bottle with capacity two liters, was used to collect samples from the various Bore wells. The samples collected from sources at various depths covering extensively populated area, commercial, agricultural and residential colonies to obtain a good representation.

All the samples were stored in sampling kits with usual care and brought to the laboratory for chemical analysis. The physio-chemical analysis was performed for pH, Conductivity, TDS, Alkalinity, Hardness, Chloride, BOD, COD, Dissolved oxygen, colour and odour. The Standard CPCB and American Public Health Association (APHA, 1998) methods were used for the analysis. Indian standards and World Health Organization (WHO Guideline) are used for water quality parameter. The standards are given as below in Table 1

Table 1: Indian Standards & WHO Guideline for Drinking Water

S/N	**PARAMETER**	**BIS, Indian Standards (IS 10500:1991)**		**World Health Organization (WHO Guideline)**
		Desirable Limit	Permissible Limit	Maximum allowable Concentration
1	Colour	5 Hazen unit	25 Hazen unit	15 true color unit
2	Turbidity	5.0 NTU	10 NTU	5.0 NTU
3	P^H	6.5 – 8.5	No relaxation	6.5 – 8.5
4	Total hardness (as $CaCo_3$)	300 mg/L	600 mg/L	500 mg/L
5	Chlorides (as CL)	250 mg/L	1000 mg/L	250 mg/L
6	Conductivity	-	-	1.400 mmhos
7	Dissolved solids	500 mg/L	2000 mg/L	1000 mg/L
8	Calcium (as Ca)	75 mg/L	200 mg/L	-
9	Dissolved oxygen	-	-	>5 mg/L
10	BOD	-	-	5 mg/L
11	COD	-	-	10 mg/L
12	Alkalinity	200 mg/L	600 mg/L	-

Source: Research gate

As per proposed work, zoning of Enugu city, Nigeria was done. Groundwater samples were collected and analyzed for physico-chemical parameters. The results are discussed in the next chapter.

III. Results and Discussion

The results of the analysis for chemical and physiochemical parameters are presented in Table 2. The significant results are discussed in foregoing paragraphs.

Table 2.: Samples analyses, physical and chemical parameters and their concerntrations

PARAMETERS	**UNITS**	**A_1**	**A_2**	**A_3**	**B_1**	**B_2**	**B_3**
pH	-	6.0	6.0	6.0	6.0	6.0	6.0
Conductivity	µs/cm	1351	535	182.3	681	880	145.4
Turbidity	NTU	75	14.61	18.5	2.49	9.32	6.56
Colour	-	colourless	Colourless	colourless	colourless	colourless	colourless
Alkalinity	mg/l	200	100	50	50	25	50
Total Dissolved Solid	mg/l	410	170	190	300	210	70
Total Hardness	mg/l	104	6	32	11.6	56	26
Chloride	mg/l	184.6	78.1	92	248.5	276.9	78.1
COD	mg/l	88	81.6	91.2	81.6	40.8	34.4
BOD	mg/l	0.3933	0.3933	0.9833	0.8850	0.7867	0.2950

Source: Pymotech Research Center

Analysis based on zoning

ZONE 1

The P^H level in zone 1 is 6.0, which is below BIS, Indian standard and WHO guidelines. In general, a water with a $P^H < 7$ is considered acidic and with a $P^H > 7$ is considered basic. The normal range for P^H in surface water system is 6.5 to 8.5 and for ground water systems 6 to 8.5. In general, a water with a low $P^H < 6.5$ could be acidic, soft and corrosive. Therefore, the water could leach metal ions such as iron, manganese, copper, lead and zinc from the aquifer, plumbing fixtures and piping.

Therefore, water with a low P^H could contain elevated levels of toxic metals, cause premature damage to metal piping and have associated aesthetic problem such as a metallic or sour taste, staining of laundry, staining of sinks and drains. Typically, water with low P^H pose health risk.

The level of conductivity in the water sample in zone 1 in the contaminated area is 1351 µs/cm (0.1351 mmhos) and uncontaminated area is 681 µs/cm (0.0681 mmhos), which is less than 1.400 mmhos, WHO guidelines. Conductivity is a measure of the ability of water to pass an electrical current. Because dissolved salts and other inorganic chemicals conduct electrical current very well and therefore have a low conductivity when in water. Conductivity is also affected by temperature the warmer the water, the higher the conductivity.

The contaminated bore well in zone 1 has a turbidity of 75 NTU which is higher than the desirable limit and permissible limit of BIS, Indian standards 5.0 NTU and 10 NTU respectively and WHO guidelines, 5.0 NTU. The uncontaminated bore well in zone 1 has a turbidity of 2.49 NTU which is less than BIS, Indian standard and WHO guidelines. The greater the scattering of light, the higher the turbidity, low turbidity values indicate high water clarity, high values indicate low water clarity which indicates that bacteria may be present. High turbidity can significantly reduce the aesthetic quality of lakes and streams, having a harmful impact on recreation and tourism. It can increase the cost of water treatment for drinking and food processing. It can harm fish and other aquatic life by reducing food supplies degrading spawning beds and affecting gill function.

The contaminated sample has an alkalinity of 200mg/L which is the same value as the desirable limit of BIS, Indian standard but lesser than the permissible limit. The uncontaminated sample has an alkalinity of 50mg/L which is less than BIS, Indian standard. If the alkalinity is much less than total hardness, it may signify elevated levels of chloride, nitrate or sulphates. Water with low levels of alkalinity (less than 150 mg/L) is more likely to be corrosive. High alkalinity water (greater than 150 mg/L) may contribute to scaling. This is a test for overall water quality. There are no health concerns related to alkalinity.

The total dissolved solids in the contaminated area and uncontaminated area in zone one are 410 mg/L and 300 mg/L respectively, which is lesser than the BIS, Indian standards and WHO guidelines. The palatability of drinking water has been rated by panels of tasters in relation to its TDS level as follows: excellent, less than 300 mg/L; good, between 300 and 600 mg/L; fair, between 600 and 900 mg/L; poor, between 900 and 1200 mg/L and unacceptable, greater than 1200 mg/L. Hence, the water samples gotten from zone one is said to be good for drinking water.

The total hardness of water in zone one has a contaminated and uncontaminated values of 104 mg/L and 11.6 mg/L respectively. These values are lesser than the BIS, Indian standard and WHO guidelines. General guidelines for classification of water are: 0 to 60 mg/L as calcium carbonate is classified as soft; 61 to 120 mg/L as moderately hard; 121 to 180 mg/L as hard; and more than 180 mg/L as very hard.

The contaminated and uncontaminated values of chloride obtained from water samples in zone one are 184.6 mg/L and 248.5 mg/L. The samples obtained from zone one has chloride lesser than the BIS, Indian standards and WHO guidelines. Chloride are harmless at low level, well water high in sodium chloride can damage plants if used for gardening or irrigation and give drinking water an unpleasant taste. Interestingly, there is no federally enforceable standard for chloride in drinking water, though the EPA recommends levels no higher than 250 mg/L to avoid salty tastes and undesirable odors. At levels greater than this, sodium chloride can complicate existing heart problems and contribute to high blood pressure when ingested in excess.

The COD values for contaminated and uncontaminated samples in zone one are 88 mg/L and 81.6 mg/L respectively. COD values in zone one is greater than WHO standard.

The BOD values for contaminated and uncontaminated samples in zone one are 0.3933 mg/L and 0.8850 mg/L respectively, which is lesser than WHO standard, 5.0 mg/L. High BOD/COD ratio indicates that toxicity is less. Low ratio indicates that toxicity is more.

UNITS/ PARAMETER	Ph	EC (µs/cm)	TURB (NTU)	ALK (mg/L)	TDS (mg/L)	TH (mg/L)	CL (mg/L)	COD (mg/L)	BOD (mg/L)
A1	6.0	1351	75	200	410	104	184	88	0.3933
B1	6.0	681	2.49	50	300	11.6	248.5	81.6	0.8850
W.H.O	6.5-8.5	1.400	5.0	-	1000	500	250	10	5

Table 3. Zone 1 results and WHO standard

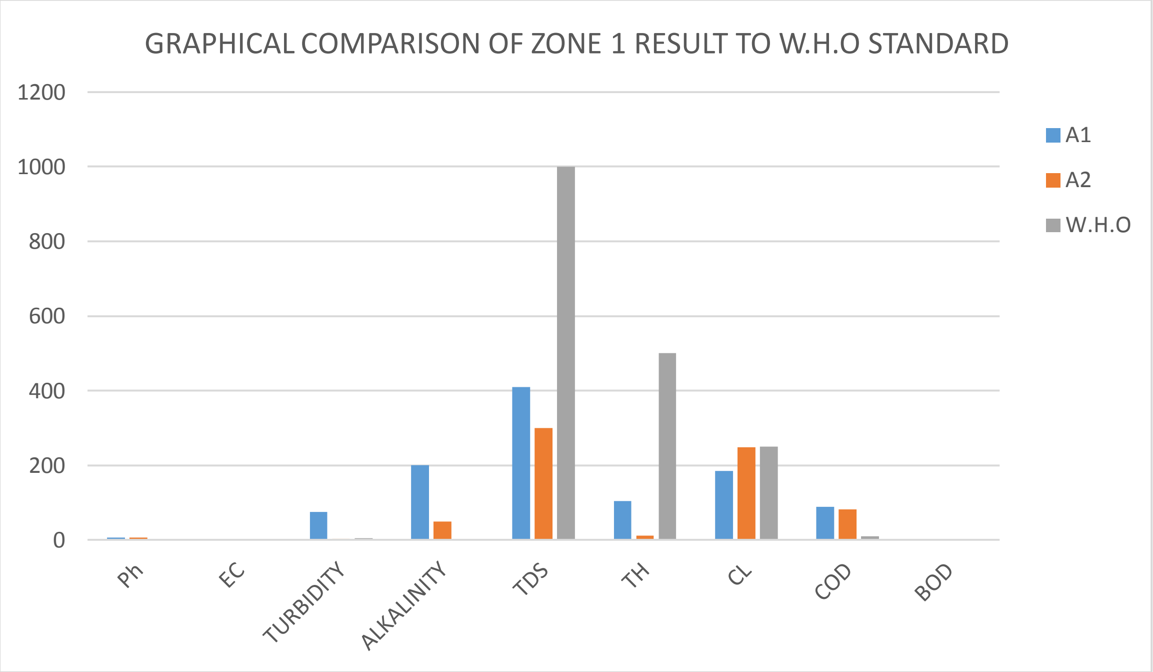

Figure 2: graphical comparison of zone 1 result to w.h.o standard

ZONE 2

The P^H level of the contaminated and uncontaminated water sample in zone 2 is 6.0, which is below BIS, Indian standard and WHO guidelines. Therefore, the water could leach metal ions such as iron, manganese, copper, lead and zinc from the aquifer, plumbing fixtures and piping. Typically, water from this zone would pose health risk.

The level of conductivity in the water sample in zone 2 in the contaminated area is 535 µs/cm (0.0535 mmhos) and uncontaminated area is 880 µs/cm (0.0880 mmhos), which is less than 1.400 mmhos, WHO guidelines.

The contaminated bore well in zone 2 has a turbidity of 14.61 NTU which is higher than the desirable limit and permissible limit of BIS, Indian standards 5.0 NTU and 10 NTU respectively and WHO guidelines, 5.0 NTU. The uncontaminated bore well in zone 2 has a turbidity of 9.32 NTU which is also higher than BIS, Indian standard and WHO guidelines. High values of turbidity indicate low water clarity which indicates that bacteria may be present and may not be suitable for drinking water unless been treated. The contaminated sample has an alkalinity of 100mg/L which is less than the desirable and permissible limit of BIS, Indian standard. The uncontaminated sample has an alkalinity of 25mg/L which is less than BIS, Indian standard. Water with low levels of alkalinity (less than 150 mg/L) is more likely to be corrosive. There are no health concerns related to alkalinity.

The total dissolved solids in the contaminated area and uncontaminated area in zone two are 170 mg/L and 25 mg/L respectively, which is lesser than the BIS, Indian standards and WHO guidelines. The palatability of drinking water has been rated by panels of tasters in relation to its TDS level as follows: excellent, less than 300 mg/L; good, between 300 and 600 mg/L; fair, between 600 and 900 mg/L; poor, between 900 and 1200 mg/L and unacceptable, greater than 1200 mg/L. Hence, the water samples gotten from zone two is said to be good for drinking water.

The total hardness of water in zone 2 has a contaminated and uncontaminated values of 6.0 mg/L and 56 mg/L respectively. These values are lesser than the BIS, Indian standard and WHO guidelines. General guidelines for classification of water are: 0 to 60 mg/L as calcium carbonate is classified as soft; 61 to 120 mg/L as moderately hard; 121 to 180 mg/L as hard; and more than 180 mg/L as very hard. Water found in this zone is classified as soft water.

The contaminated and uncontaminated values of chloride obtained from water samples in zone one are 78.1 mg/L and 56 mg/L. The samples obtained from zone one has chloride lesser than the BIS, Indian standards and WHO guidelines. Chloride are harmless at low level.

The COD values for contaminated and uncontaminated samples in zone one are 81.6 mg/L and 40.8 mg/L respectively. COD values in zone one is greater than WHO standard.

The BOD values for contaminated and uncontaminated samples in zone one are 0.3933 mg/L and 0.7867 mg/L respectively, which is lesser than WHO standard, 5.0 mg/L. High BOD/COD ratio indicates that toxicity is less. Low ratio indicates that toxicity is more.

UNITS/ PARAMETER	Ph	EC (µs/cm)	TURB (NTU)	ALK (mg/L)	TDS (mg/L)	TH (mg/L)	CL (mg/L)	COD (mg/L)	BOD (mg/L)
A2	6.0	535	14.61	100	170	6	78.1	81.6	0.3933
B2	6.0	880	9.32	25	210	56	276.9	40.8	0.7867
W.H.O	6.5-8.5	1.400	5.0	-	1000	500	250	10	5

Table 4. Zone 2 results and WHO standard

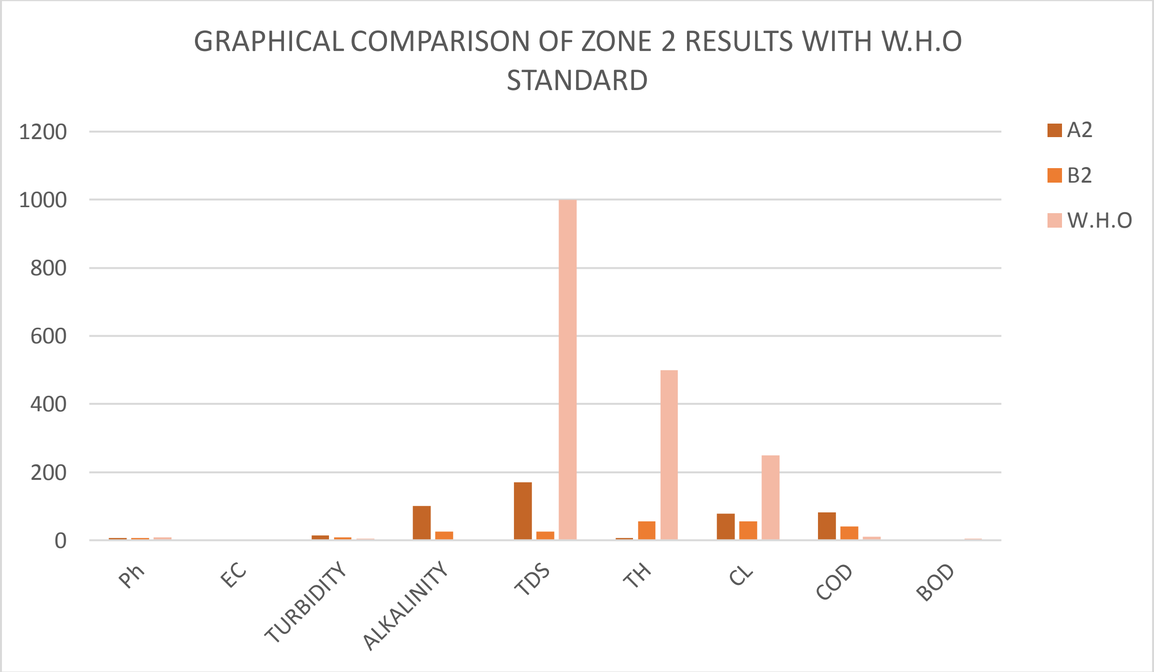

Figure 3: graphical comparison of zone 2 result to w.h.o standard

ZONE 3

The P^H level of the contaminated and uncontaminated water sample in zone 3 is 6.0, which is below BIS, Indian standard and WHO guidelines. P^H values less than 7.0 is considered acidic, hence water from this zone would pose health risk.

The level of conductivity in the water sample in zone 3 in the contaminated area is 182.3 µs/cm (0.01823 mmhos) and uncontaminated area is 145.4 µs/cm (0.01454 mmhos), which is less than 1.400 mmhos, WHO guidelines.

The contaminated bore well in zone 3 has a turbidity of 18.5 NTU which is higher than the desirable limit and permissible limit of BIS, Indian standards 5.0 NTU and 10 NTU respectively and WHO guidelines, 5.0 NTU. The uncontaminated bore well in zone 3 has a turbidity of 6.56 NTU which is also higher than BIS, Indian standard and WHO guidelines. High values of turbidity indicate low water clarity which indicates that bacteria may be present and may not be suitable for drinking water unless properly treated.

The contaminated sample in zone 3 has an alkalinity of 50 mg/L which is less than the desirable and permissible limit of BIS, Indian standard. The uncontaminated sample has an alkalinity of 50mg/L which is less than BIS, Indian standard. Water with low levels of alkalinity (less than 150 mg/L) is more likely to be corrosive. Hence, water from this zone is said to be corrosive and could cause damage to pipelines.

The total dissolved solids in the contaminated area and uncontaminated area in zone 3 are 190 mg/L and 70 mg/L respectively, which is lesser than the BIS, Indian standards and WHO guidelines. The palatability of drinking water has been rated by panels of tasters in relation to its TDS level as follows: excellent, less than 300 mg/L; good, between 300 and 600 mg/L; fair, between 600 and 900 mg/L; poor, between 900 and 1200 mg/L and unacceptable, greater than 1200 mg/L. Hence, the water samples gotten from zone three is said to be excellent, which is considered safe for drinking water.

The total hardness of water in zone 3 has a contaminated and uncontaminated values of 32 mg/L and 78.1 mg/L respectively. These values are lesser than the BIS, Indian standard and WHO guidelines. General guidelines for classification of water are: 0 to 60 mg/L as calcium carbonate is classified as soft; 61 to 120 mg/L as moderately hard; 121 to 180 mg/L as hard; and more than 180 mg/L as very hard. Water found in this zone is classified as soft water. Hence, it is good for domestic use.

The contaminated and uncontaminated values of chloride obtained from water samples in zone three are 92.0 mg/L and 78.1 mg/L. The samples obtained from zone three has chloride lesser than the BIS, Indian standards and WHO guidelines. Chloride are harmless at low level.

The COD values for contaminated and uncontaminated samples in zone three are 91.2 mg/L and 34.4 mg/L respectively. COD values in zone three is greater than WHO standard.

The BOD values for contaminated and uncontaminated samples in zone two are 0.9833 mg/L and 0.2950 mg/L respectively, which is lesser than WHO standard, 5.0 mg/L. High BOD/COD ratio indicates that toxicity is less. Low ratio indicates that toxicity is more.

UNITS/ PARAMETER	Ph	EC (µs/cm)	TURB (NTU)	ALK (mg/L)	TDS (mg/L)	TH (mg/L)	CL (mg/L)	COD (mg/L)	BOD (mg/L)
A3	6.0	182.3	18.5	50	190	32	92	91.2	0.9833
B3	6.0	145.4	6.56	50	70	26	78.1	34.4	0.2950
W.H.O	6.5-8.5	1.400	5.0	-	1000	500	250	10	5

Table 5. Zone 3 results and WHO standard

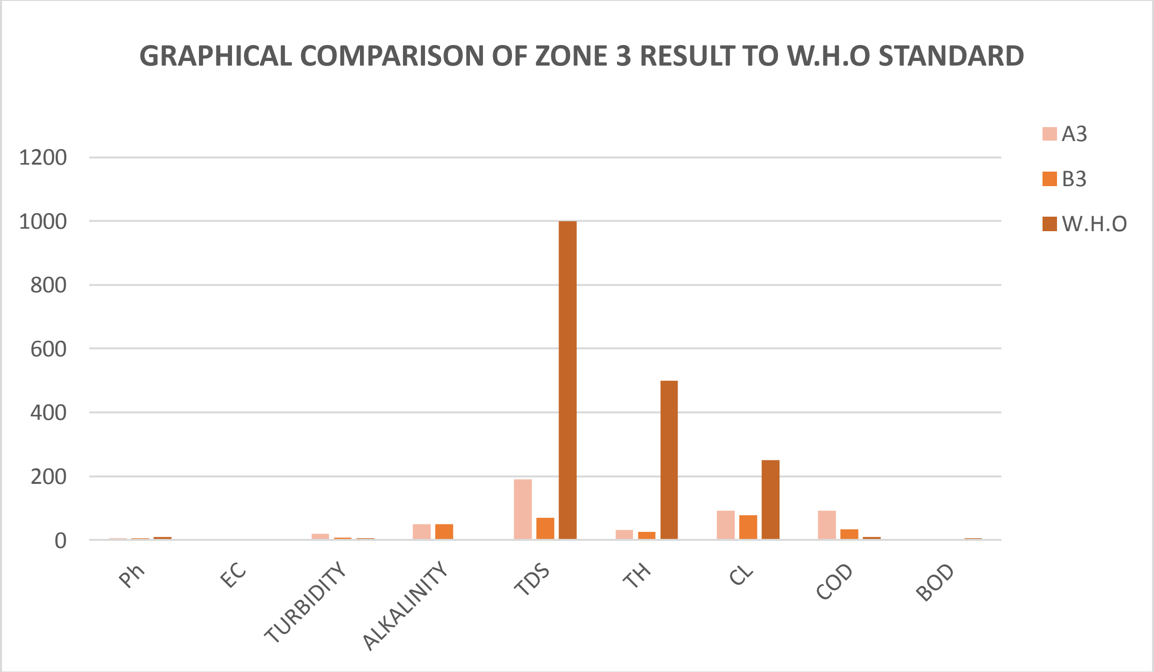

Figure 4: graphical comparison of zone 3 result to w.h.o standard

IV. Conclusion

Based on the test conducted on the samples and the results obtained, the probable sources of pollutants for groundwater pollution could be as a result of one of the following: Water logged area, Sewage treatment plant, Pollution of surface water, Black cotton soil causes rupture of sewerage system.

A wide range of distributed potential source of ground water pollution is the septic tank in most urban settlement. It is very important to provide reasonable safe distance between the treatment units and drinking water sources to avoid recontamination by leakage or accidental spills. The soil types and existing hydrogeological conditions play an important role while deciding the safe distance parameters. If this minimum distance is not adhered to, there will be a build-up of pollutants in the area. Proper management of sewage disposal and treatment systems is an ideal solution to this problem. Groundwater samples analyzed for physio-chemical parameters suggest further deterioration in the groundwater quality as compared to values gotten after the test. The water sample analysis reports from contaminated and uncontaminated area could not help to understand the impact of untreated sewage disposal on groundwater quality. The groundwater quality parameters like EC, Cl-, COD, were above the maximum permissible limit prescribed by WHO and BIS. According to this study, the groundwater within the area where the samples were obtained in Enugu city is not suitable for drinking purposes in most of the areas. To restore the groundwater quality, conventional treatment methods are available but these methods may prove to be very costly giving consideration to economics of the State. Precautionary measures will be a good step to improve the quality of groundwater in Enugu State. In which sewerage system up to the whole limits of Enugu must be provided and decentralized sewage treatment system is provided to the Enugu State. Wherever inevitable, the groundwater must be treated to desired standards prior to its intended use. Various suggestion of remedial measures for Enugu city includes: Sewerage system, Sewage treatment plant, Disposal of sewage into waterlogged area, Artificial recharge of groundwater, Bioremediation, Sewerage System, Public Awareness.

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