EFFECT OF EFFLUENT FROM SOAP INDUSTRY ON THE PHYSICO-CHEMICAL PARAMETERS OF NEARBY WELL WATER

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ABSTRACT

The physico-chemical parameters of industrial effluent generated from production of soap and hand-dug well water around the effluent open drainage had been investigated; with a view to determining the impact of the effluent on the well water in the study area. Soap effluent collected weekly for four weeks and seven well water (collected twice each in wet and dry seasons) samples were analysed for their physico-chemical parameters including water temperature, pH, total dissolved solids (TDS), apparent colour, turbidity and conductivity using standard methods. Other parameters analysed were : alkalinity, acidity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS) and Cl^- using standard methods. Major anions such as SO_4^{2-}, NO_3^- and PO_4^{3-} were determined using UV-Visible spectrometric method. Sodium, K, Ca Mg, and heavy metals (Cd, Cr, Cu, Fe, Mn, Pb and Zn) were determined using Atomic Absorption Spectrophotometry (AAS). The physico-chemical parameters of effluents from soap industry obtained ranged: BOD (125.28±0.39 – 228.00±3.11 mg/L), COD (243.03±0.04 – 277.66±0.09 mg/L), turbidity (300.90±1.27 – 320.50±0.71 NTU), apparent colour (2922.80±0.00 – 3146.71±0.14 Pt.-Co.), TSS (463.00±4.24 – 4169.00±12.73 mg/L), PO_4^{3-} (4.73±0.01 – 6.11±0.01 mg/L) and Cr (0.08±0.01 –

0.25±0.01 mg/L). These values were above Nigerian standards - National Environmental Standards and Regulations Enforcement Agency (NESREA). The pH of soap effluent ranged from 6.16±0.03 to 10.22±0.16. Meanwhile, the physico-chemical parameters of well water samples showed that turbidity (10.17 – 153.91 NTU), apparent colour (11.99 – 1803.30 Pt.-Co.), pH (8.60 – 10.30), BOD (50.54 – 58.18 mg/L), PO_4^{3-} (5.21 – 7.08 mg/L), Cl^- (264.15 – 276.25 mg/L), TSS (178.00 – 375.50 mg/L), TDS (660.50 – 782.50 mg/L) and conductivity (1102.00 – 1307.00 µS/cm) of some wells located close to the effluent drainage were above World Health Organisation (W.H.O.) drinking water quality standard. The range of values obtained in the entire wells in both seasons for Cd, Cr and Pb were above W.H.O. standard while Fe, Mn , Cu and Zn were below W.H.O. standard.

The study concluded that the level of pollution of soap effluents had exceeded the permissible levels and the well waters in the study area were negatively impacted.

Key words: effluent, groundwater, NESREA, physico-chemical, soap, well-water

INTRODUCTION

Industrialization plays a vital role in growth and development of any country and it started earlier in UK than U.S.A, thereafter industries are established in advance as well as under developed/developing countries (Nasrullah *et. al,.* 2006). In Nigeria, industrial establishment was dated to colonial-independent times when large and small cottage industries began operation. Ajayi and Osibanjo, (1981) affirmed that industrialization and effluent discharges into the environment have been on the increase in Nigeria since 1960, thus the effluent had both direct and indirect adverse effect on our environmental components such as air, soil, water and human health due to apathy of the industrialist towards the treatment of the effluent from their respective units prior to discharges into the environment. Industrial usage of water commonly adds contaminants and chemicals to be discharged, these discharges usually contain specific pollutants which are related to the nature of products handled in an industry and the process followed (Narayanan, 2011). Ballance and Bartram (1996) affirmed that industrial effluent may contain toxic chemicals such as organic and/or inorganic depending on the industrial process. Grate quantities of untreated industrial effluents are discharged directly to surface water causing serious pollution. However, the components of environment as air, water and soil are not without some undesirable, hazards and pathogens but at no or low concentrations below the permissible standards.

According to W.H.O. (2011) access to safe drinking water is important as a health and development issues at a national, regional and local level as well is essential to sustain life and a satisfactory (adequate, safe and accessible) supply must be available to all. Finite supply of usable water includes rivers, lakes, oceans, and underground aquifers. UNESCO, (2003), estimates that globally groundwater provides about 50% of current portable water supplies, 40% of the demand of self-supplied industries and 20% of water use in irrigated agriculture. In Africa, groundwater is the most realistic water supply option for meeting dispersed rural and industrial water demand (Foster, *et. al,.* 2000; Ocheri and Ahola, 2007). UNICEF (2008) affirmed that groundwater is the most common water sources, especially in urban, rural and sub-urban areas in developing countries. Groundwater plays an important role in the social and economic life of the people in terms of domestic, industrial and agricultural use (Edet *et al.,* 2011). Residential, municipal, commercial, agricultural and industrial activities can all affect groundwater quality (USEPA, 1994); significant changes in land use pattern, enormous industrial effluent entering the hydrological cycle stresses the quality and quantity of groundwater (Mackey, 1990; Ocheri and Ahola, 2007).

In Osogbo, families dug wells are common and are usually outside. However, the wells are often poorly constructed and are rarely well-sealed against contamination. Exacerbating the problem further, because of lack of space and knowledge, wells are dug close to storm water run-offs pathways, gutters and near dumpsites. Present study was carried out at Surulere area, Osogbo to determine the physico-chemical parameters of soap effluent and hand-dug wells around the effluent drainage, with a view to determining the impacts of the industrial effluent on the well water in the area.

MATERIALS AND METHODS

This study was carried out at Surulere Community (Kasmo Area), Oke-Baale, Osogbo, Osun State Southwestern Nigeria. Plate 1: Map of the Study Site and Sampling Locations.

Sampling

Soap industry began production in Surulere area in early 2000, ever since the industry started production; there have been no functioning wastewater treatment facilities within its premises. Waste waters are discharged at every stage of production including wash water into open drainage of a single lane road in the community. The untreated soap effluents were collected weekly for four weeks and seven wells (Plate 1, located around effluent drainage) were sampled twice in wet-

July and August, 2013 and dry- December, 2013 and January, 2014. Temperature, pH, turbidity, conductivity, total suspended solids (TSS), total acidity, total alkalinity, chloride, sulphate, nitrate, phosphate, chemical oxygen demand (COD), biological oxygen demand (BOD), dissolved oxygen (DO) were determined. Others include Na, Ca, K, Mg, Cd, Cr, Cu, Fe, Mn, Pb and Zn. Water temperature was determined *in situ* and dissolved oxygen was fixed *in-situ*; other parameters were analysed in the Hyrobiology Laboratory, Zoology Department of Obafemi awolowo University, Ile-Ife. Metals were determined at Centre for Energy Research and Development of the same institution.

Experimental

Temperature was determined using graduated mercury in-bulb thermometer, apparent colour was determined on unfiltered samples colorimetrically using Potassium Chloroplatinate-cobalt (Pt-Co.) solutions standards, while turbidity was determined nephelometrically by comparison with turbidity (NTU) standards (APHA, *et. al.,* 1998). pH and conductivity were determined using pH-meter and conductivity meter respectively. Dissolved oxygen (DO) was determined using Winkler methods while biochemical oxygen demand (BOD) was determined by dilution method (Golterman, *et. al*., 1978). Chemical oxygen demand (COD) was determined by dichromate digestion method, chloride by mercuric nitrate method (APHA, *et. al.,* 1998). The nitrate ion was analysed using brucine-sulphanlinic acid method, the phosphate by the vanadomolybdo-phosphoric acid colorimetric method and the sulphate by the turbidimetric method (Ademoroti, 1996).

The total solids (TS) as well as total dissolved solids (TDS) of samples were determined gravimetrically after oven drying them to constant weight at 105 ± 2°C (USEPA, 1998). Total suspended solids (TSS) were calculated as the difference between TS and TDS. Total acidity, Total alkalinity were determined by titrimetric methods (Golterman, *et. al*., 1978). Sodium, k, Ca, Mg, Cd, Cr, Cu, Fe, Mn, Pb and Zn were determined using Perkin Elmer 400 Atomic Spectrophotometer (AAS). Sample collection, preparation and treatment were carried out according to the standards (APHA *et. al.,* 1998). All the chemicals used were of analytical reagent grade and all the equipment were checked and calibrated according to the manufacturer's specifications. Duplicate analyses of the samples were run. Data were analysed using Microsoft Excel, Past and SPSS.

RESULTS

Soap Effluent and Well Water Analyses:

The result obtained for the physico-chemical parameters of soap effluent is presented in Table 1; as well, well water results are as presented in Figures 1a – 3b.

Physical Parameters (Temperature, Apparent Colour, Turbidity, TDS, TSS, Conductivity)

Effluent mean temperature ranged from 28.29±0.042 ^oC to 28.80±0.141 ^oC, Table 1. Results of physical parameters measured of the well water are shown in Figures 1a and 1b, respectively. The mean values of well water temperature during wet season ranged from 22.5±0.707^oC to 26.00±0.000^oC (Fig.1a) and ranged from 24.25±0.354^oC to 26.75±0.345^oC in dry season (Fig. 1b).

The mean values of apparent colour and turbidity in soap effluent ranged from 2922.8±0.001 Pt.-Co. to 3147.71±0.140 Pt.-Co. and 300.9±1.237 NTU to 320.5±0.707 NTU respectively. The mean values of well water apparent colour during the wet season ranged from 91.96±11.31 Pt.-Co to 757.18±167.5 Pt.-Co.(Fig.1a) and ranged from 11.99±0.000 Pt.-Co to 1803.26±0.000 Pt.-Co. in dry season

(Fig.1b). The mean turbidity values of well water in the wet season ranged from 10.17±4.617 NTU to 55.91±9.421 NTU (Fig. 1a) and ranged from 0.190±0.262 NTU to 153.91±0.000 NTU in the dry season (Fig. 1b).

The total suspended solids (TSS), total dissolved solids (TDS) and conductivity values were ranged between 2476.1±8.344 mg/L and 4169.0±12.73 mg/L; 140.3±0.424 mg/L and 345.0±7.071 and 233.0±4.330 µS/cm and 573.0±4.243 µS/cm, respectively in effluent. The TSS mean values in well water during wet season ranged from 51.40±0.565 mg/L to 201.50±28.99 mg/L and from 50.45±37.26 mg/L to 375.50±55.86 mg/L in dry season. The TDS mean values during wet season ranged from 61.60±4.808 mg/L to 660.5±41.72 mg/L and ranged from 43.70±8.343 mg/L to 782.5±38.89 mg/L in dry season. The conductivity mean values of well water varied from 88.15±6.858 µS/cm to 1102.0±69.29 µS/cm in wet season and ranged from 72.75±14.07 µS/cm to 1307.0±63.63 µS/cm in dry season.

Chemical parameters (pH, Total Alkalinity, Total Acidity, DO, BOD_5 and COD)

The range of values of pH of effluent ranged from 6.16±0.028 to 10.22±0.156. Total acidity of the effluent ranged from zero to 164.0±5.657 mg$CaCO_3$/L while the total alkalinity ranged from 16.50±0.707 mg$CaCO_3$/L to 156.0±7.071 mg $CaCO_3$/L, respectively (Table 1).

Analyses of chemical parameters of well water are presented in Figures 2a and 2b. The mean pH of the well water during wet season varied from 6.18±0.035 to 10.30±0.141and ranged from 6.38±0.177 to 10.05±0.212 in dry season. The mean acidity of the wells during wet season ranged from 17.0±1.414 mg$CaCO_3$/L to 59.30±0.989 mg$CaCO_3$/L and ranged from 31.00±21.21 mg$CaCO_3$/L to 82.00±0.800 mg$CaCO_3$/L in the dry season. The mean values of alkalinity of the wells in the wet season ranged from 33.64±1.464 $mgCaCO_3$/L to 544.0±16.97 $mgCaCO_3$/L and ranged from 32.50±2.12 $mgCaCO_3$/L to 684.5±120.9 $mgCaCO_3$/L in the dry season.

The DO of the effluent ranged between 1.600±0.238 mg/L and 3.00±0.849 mg/L. The mean concentrations of BOD_5 ranged from 125.28±0.396 mg/L to 228.0±3.112 mg/L. A range of 243.03±0.042 mg/L to 277.66±0.085 mg/L was obtained for COD.

The mean DO values in wet season ranged from 0.600±0.283 mg/L to 4.71±0.049 mg/L and ranged from 0.00 mg/L to 4.10±2.40 mg/L in dry season. BOD_5 mean concentration ranged from 47.34±3.288 mg/L to 58.18±8.817 mg/L and from 38.64±10.66 mg/L to 48.04±0.00 mg/L in wet and dry seasons respectively. COD mean concentration ranged from 23.11±1.433 mg/L to 32.08±5.697 mg/L and from 23.83±4.523 mg/L to 32.48±6.165 mg/L in wet and dry seasons respectively.

Anions (SO_4^{2-}, NO_3^-, Cl^- and PO_4^{3-}) and Metals (Na, K, Ca and Mg)

The anions concentrations ranges of values SO_4^{2-} (11.13±0.017 – 72.4±0.014 mg/L), NO_3^- (11.64±0.057 – 20.21±0.018 mg/L), Cl^- (19.55±0.712 – 82.22±0.311 mg/L) and PO_4^{3-} (4.730±0.009 – 6.105±0.007 mg/L), Table 1, were obtained for soap effluent. In the wet season, sulphate concentrations ranged from 12.52±1.138 mg/L to 77.19±2.390 mg/L, nitrate concentrations ranged from 0.667±0.017 mg/L to 1.557±0.609 mg/L, phosphate from 4.340±0.562 mg/L to 7.080±1.362 mg/L and chloride from 38.37±8.676 mg/L to 276.25±33.16 mg/L, respectively (Figures 3a and 3b). The concentrations obtained in the dry season ranged from: 12.73±0.849 mg/L to 78.87±1.633 mg/L, 0.315±0.049 mg/L to 1.212±0.037 mg/L, 3.430±0.968 mg/L to 6.510±2.736 mg/L and 25.05±2.609 mg/L to 264.15±73.03 mg/L for sulphate, nitrate, phosphate and chloride, respectively (Figures 3a and 3b).

The ranges of values Na: (0.633±0.011 – 1.229±0.001 mg/L), K (2.112±0.001 – 5.354±0.005 mg/L), Ca (1.443±0.006 – 5.422±0.007 mg/L) and Mg (2.001±0.001 –

2.714±0.004 mg/L) were obtained for soap effluent samples. The highest concentration of metal recorded was Ca with a mean concentration of 54.68±9.673 mg/L(well 7) during the wet season while a lowest mean value of 0.753±0.129 (well 6) was recorded for Mg in samples collected from the wells during the dry season, (Figures 3a and 3b).

Heavy Metals

Heavy metal such as Cd, Cr and Cu had their mean values between 0.077±0.005 mg/L and 0.251±0.009 mg/L while Fe, Mn, Pb and Zn ranged between 0.004±0.007 mg/L and 0.110±0.011 mg/L for soap effluent studied, Table 1. Figures 4a and 4b show the results of heavy metals in well water samples. The highest mean concentration of heavy metals detected was Zn with concentration of 0.289±0.019 mg/L (well 2, wet season). The highest mean concentration for Pb was found to be 0.149±0.054 mg/L (well 4, wet season); 0.253±0.040 mg/L (well 5, wet season) for Cr, and 0.164±0.052 mg/L (well 7, wet season) for Cd while the highest mean concentrations found for Mn, Fe and Cu were 0.098±0.008 mg/L (well 5, wet season), 0.141±0.130 mg/L (well 5, wet season) and 0.136±0.065 mg/L (well 5, wet season), respectively.

DISCUSSION

The values of effluent temperature measured are below the NESREA permissible limit for wastewater discharged into the environment, Table 1. Well water temperatures were higher in dry season than wet season indicating the intensity of sunlight being higher in the dry season than the rainy season. The temperature values were within the permissible limits (40 ^{o}C) of W.H.O. (2008) standards (Fig 1a and 1b). High temperature reduced solubility of oxygen and amplified odour due to anaerobic reaction (Ademoroti, 1996).

Natural waters colour range from <5 Pt-Co unit in very clear waters to 300 Pt-Co in dark peaty waters (Chapman, 1996). All the mean values observed for apparent colour were above NESREA limit value and this could be associated with high coloured organic dye used in soap production, production efficiency and inept attitude of industrialist towards wastewater treatment. Likewise, the turbidity values of soap effluent were above the NESREA limits of 5.00 NTU; continuous discharge into the environment could lead to increased organic matter in the environment which may cause health hazard on both aquatic organisms and human beings.

The apparent colour and turbidity values of well water were higher in wet season than dry season except in well 4 (turbidity) and well 5 (apparent colour and turbidity) where the results were vice-versa. High apparent colour and turbidity values in wet season could be attributed to the combined effects of characteristic coloured effluent from soap industry infiltrating into the wells. The significant increase during the wet season is attributed to increased precipitation and increased percolation of surface run-off into the groundwater. Though high turbidity is often a sign of poor water quality and land management, crystal clear water does not always guarantee healthy water.

Total dissolved solids and conductivity values were lower than NESREA permissible limits, however, TSS values were much higher than NESREA limit which is 10 mg/L for soap effluent. The high TSS values could be attributed to large residue in soap wastewaters during production. The effect of presence of total suspended solids is the turbidity due to silt and organic matter (Mahananda, *et. al.,* 2011).

Meanwhile, mean values obtained for the well 4 and well 5 (both dry and wet seasons) are much higher than the recommended 150 mg/L limit by the Nigerian Standard for Drinking Water Quality (NSDWQ (SON), 2007), other wells have TSS values below permissible safe limit. Higher values of TSS can also lead to increased turbidity. The TDS and conductivity mean values were within the recommended 500 mg/L and 1000 v µS/cm limit by (W.H.O., 2008) except for well 4 (both seasons) whose value is above the limit; hence, attributed to catchments' geology, or soap effluent impacts. Conductivity itself is not of human or aquatic health concern but it can serve as an indicator of other water quality problems. Some but not the entire dissolved solids act as conductors and contribute to conductance. Water with high TDS often has a bad taste and/or high water hardness, and could result in a laxative effect. Water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste (Brown and Caldwell, 2004). However, well water conductivity mean values followed similar pattern as total dissolved solids in both seasons. The remarkable increase in conductivity in the dry season is possibly due to high evapo-transpiration process which resulted in the high concentration of the ions in the water (Allan, 2001).

The mean pH values are slightly acidic for samples in weeks 2 and 3 and were below NESREA limits while weeks 1 and 4 had alkaline pH which is above the permissible limits of 6 to 9 for chemicals, soap and detergent effluent discharge into the environment. The effluent with pH <7 was associated with water at preparatory stage of production, while alkaline values obtained were associated with materials being used for soap production containing compounds of sodium or potassium and final stage of production. Acidic water is not frequently encountered except in the cases of severe pollution, Narayanan (2011). The no or low acidity results obtained in soap effluent might be associated primarily with chemical compositions involved in soap manufacturing process.

The range of desirable pH values of water prescribed for drinking purposes is 6.5 – 8.5 (W.H.O, 2008), however, well 2, well 3, well 4, well 5 and well 6 pH values were outside this range in wet season (Figure 2a), while well 2, well 4, well 5 and well 6 pH values were outside this range in dry season (Figure 2b). The high mean pH values obtained from samples from those wells might be connected with groundwater recharges via infiltration from effluent runoff from soap. It might be due to the presence of dissolved substances coming from bedrocks, soils and other materials in the soil because basic rocks such as limestone contribute to higher pH values, (Brown and Caldwell, 2004). Human activity such as water guard treatment chemicals which were used by the residents could also be responsible for high pH values recorded.

The well water acidity values were higher in dry season than wet season. This could be attributed to reduced precipitation resulting into low infiltration of effluents into groundwater. Acidity values lower than 70 $mgCaCO_3/L$ indicates the impact of bedrock substances (Chapman, 1996), however, well 5, well 6 and well 7 acidity values in dry season were higher than 70 $mgCaCO_3/L$ indicates impact of discharged effluents. Water system with low alkalinity below 10 $mgCaCO_3/L$ is poorly buffered, and is very susceptible to changes in pH from natural and human-caused sources. Levels of 20-200 $mgCaCO_3/L$ are typical of fresh water. A total alkalinity level of 100-200 $mgCaCO_3/L$ will stabilize the pH level in water (Brown and Caldwell, 2004). In this study, well 4, well 5 and well 6 mean alkalinity values were above 200 $mgCaCO_3/L$ the safety range values described above in both seasons, thus, impacted by soap effluent. Alkalinity itself has little public health significance, although highly alkaline waters are unpalatable and can cause gastrointestinal discomfort.

The low DO in soap effluent could be attributed to the presence of high turbid matters making oxygen dissolution in samples difficult and in addition oxygen will diffuse into cold water at a higher rate than when diffuse into warm water. Both BOD_5 and COD values were higher than the permissible limits (NESREA); these could be attributed to high pollution load and presence of a high content of biodegradable organic pollutants in the effluent from the industry.

Generally, well water DO values were higher in wet season than dry season. This is attributed to seasonal fluctuation and the effect of temperature on the solubility of oxygen in water. At high temperature, the solubility of oxygen decreases while at lower temperature, it increases (Plimmer, 1978). Akpan, (2004) also observed that tropical African aquatic systems generally have low DO in the dry season than the wet season. The low DOs in some wells could be attributed to the fact that groundwater has no natural re-aeration process available, so once depleted, groundwater DO will remain very low. The trend of seasonal variation in BOD values followed that of DO concentration with higher values during the rainy season than in the dry season. The wet season increase in BOD_5 values was probably due to the increased input of decomposable organic matter into the wells through effluent discharges aided by high precipitation. However, the BOD_5 studied for each well revealed that values exceeded the safe limit for drinking water quality of W.H.O. (2008) in well 3, well 4, well 5, well 6 and well 7 in wet season, (Figure 2a).

The COD mean concentrations are above the permissible limits- 10 mg/L, (W.H.O., 2008).

Industrial effluent discharged containing SO_4^{2-} may increase not only the concentrations of the ion in surface waters, but also the concentration of H^+ in freshwater environments without much acid-neutralizing capacity. Likewise effluents discharge containing nitrate and phosphate lead to eutophication process in water body, likewise chloride increases with the increasing degree of eutrophication. For the anions concentrations, nitrate and phosphate values were higher than NESREA standard limits, others were below the limit. The mean values obtained from well waters in the study areas showed concentration of nitrates, sulphates, phosphates and chlorides to be generally higher in the wet season than dry season. This is also attributed to the increase frequency of discharging of effluent and rainfall during the period, and well waters' treatment processes employed by the residents. The Nigerian Drinking Water Standards has set a safety value of 50 mg/L and 5 mg/L for NO_3^- and PO_4^{3-} respectively while a safety value of 250 mg/L has been recommended for chlorides and 100 mg/L for sulphates in drinking water. Phosphate limits meant for domestic uses were exceeded in well 5 and 7 in wet season, and in well 6 in both seasons. Mean values of chloride was also above the stipulated 250 mg/L limit in well 4. This is an attestation of the use of chlorine in treatment methods of the wells in the study area and effluent impact.

Sodium, potassium, calcium and magnesium mean concentrations in effluent were lower than NESREA limit standards. The high mean concentration values observed in well water in wet season (Figure 3a) samples might be connected with dissolution of basic rocks such as limestone which contributed to higher pH values observed for the period compared to those obtained for the dry season. However, the main group metals analysis shows Ca >Na>K>Mg order. All the average values were lower than the recommended safe limits of Nigerian Standards for Drinking Water Quality, (NSDWQ (SON), 2007)).

For effluent, chromium values are above NESREA limits while other heavy metals have their values below the said standard limits Table 1. Mean concentration of Cu, Zn, Fe and Mn were below the permissible limits in both seasons, while Cd and Cr exceeded permissible limits in both seasons, Pb concentrations exceeded W.H.O permissible limits in wet season only.

CONCLUSION

Soap industry discharges organic pollution load, high TDS, TSS, conductivity, apparent colour, turbidity, alkalinity, and acidic to alkaline pH and phosphate. The effect of untreated effluent from soap industry has accumulated over years resulting into pollution of groundwater located around the effluent's drainage. This is a situation that should alert the National Environmental Standards and Regulations Enforcement Agency (NESREA) to continuously monitor industrial effluents and enforce Nigeria's Environmental Laws. The study concluded that the level of pollution of soap effluents had exceeded the permissible levels and the well water in the study area were negatively impacted.

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Plate 1: Map of the Study Site and Sampling Locations

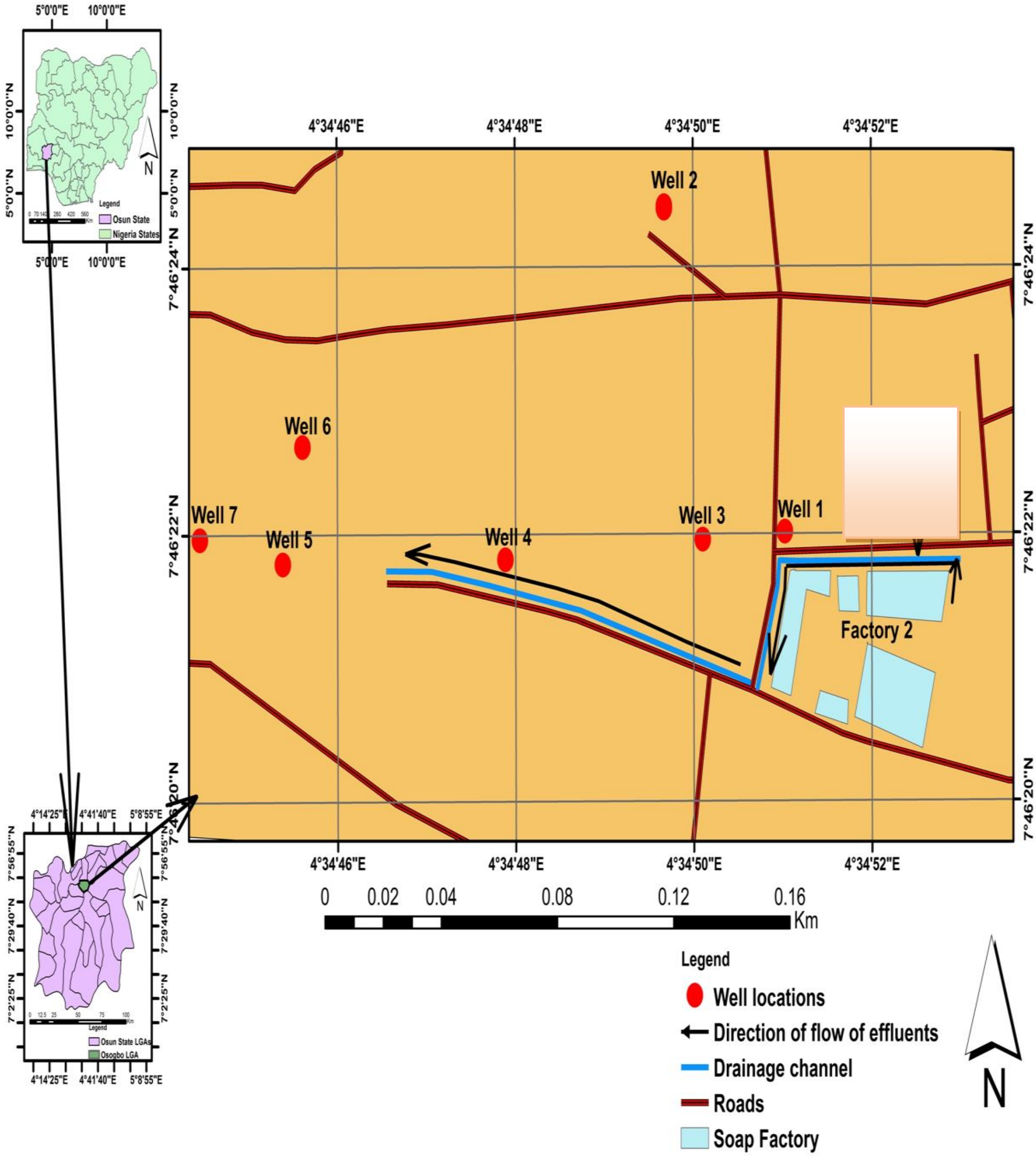

Table 1: Mean Values of Physico-chemical Parameters of Soap Effluent

Parameters	Wee k1	Week 2	Week 3	Week 4	NESREA
Water temperature °C	28.75±0.028	28.29±0.042	28.80±0.141	28.50±0.283	40.0
Apparent colour Pt.-Co.	3050.7±0.028	2922.8±0.001	3146.71±0.140	3114.73±0.04	Colourless
Turbidity (NTU)	307.45±0.071	300.9±1.273	320.5±0.707	317.25±0.071	5.0
pH	10.21±0.141	6.180±0.014	6.160±0.028	10.22±0.156	6.0-9.0
Acidity (mg$CaCO_3$/L)	ND	62.00±2.828	164.0±5.657	ND	-
Alkalinity(mg$CaCO_3$/L)	58.00±4.243	17.00±1.411	16.50±0.707	156.0±1.440	-
DO (mg/L)	2.400±0.567	3.00±0.849	1.60±0.238	2.520±0.0003	3.0
BOD (mg/L)	228.0±3.112	125.28±0.396	216.88±1.245	144.51±0.495	200.0
COD (mg/L)	254.22±0.901	243.03±0.042	277.66±0.085	274.52±0.056	40.0
TSS (mg/L)	463.0±4.242	2476.1±8.344	4169.0±12.73	3176.0±8.485	10.0
TDS (mg/L)	345.00±7.071	140.3±0.424	320.0±2.828	275.0±0.005	500.0
Conductivity (µS/cm)	573.0±4.243	233.0±4.330	539.0±12.74	456.0±8.887	1000.0
Sulphate (mg/L)	72.4±0.014	11.13±0.017	18.06±0.078	18.05±0.141	100.0
Nitrate (mg/L)	15.95±0.007	11.64±0.057	20.21±0.018	13.87±0.127	10.0
Chloride (mg/L)	56.40±0.084	26.88±0.155	19.55±0.721	82.22±0.311	100.0
Phosphate (mg/L)	4.850±0.411	5.885±0.707	6.105±0.007	4.730±0.009	2.0
Na (mg/L)	1.229±0.001	0.922±0.007	1.114±0.009	0.633±0.011	NA
K (mg/L)	2.222±0.003	3.271±0.001	2.112±0.001	5.354±0.005	NA
Ca (mg/L)	1.722±0.004	1.433±0.006	1.820±0.003	5.422±0.007	NA
Mg (mg/L)	2.244±0.005	2.111±0.011	2.001±0.001	2.714±0.004	NA
Cd (mg/L)	0.089±0.003	0.095±0.001	0.080±0.001	0.085±0.007	0.1
Cr (mg/L)	0.251±0.009	0.248±0.007	0.126±0.008	0.077±0.005	0.01
Cu (mg/L)	0.121±0.003	0.165±0.006	0.116±0.011	0.119±0.001	1.0
Fe (mg/L)	0.029±0.008	0.038±0.003	0.051±0.003	0.089±0.006	2.0
Mn (mg/L)	0.080±0.009	0.072±0.005	0.066±0.008	0.069±0.002	1.0
Pb (mg/L)	0.010±0.004	0.007±0.005	0.004±0.007	0.005±0.007	0.1
Zn (mg/L)	0.079±0.006	0.110±0.011	0.071±0.001	0.102±0.005	5.0

S.D= Standard Deviation, ND = Not Detected, NA = Not Available
NESREA= National Environmental Standards and Regulations Enforcement Agency

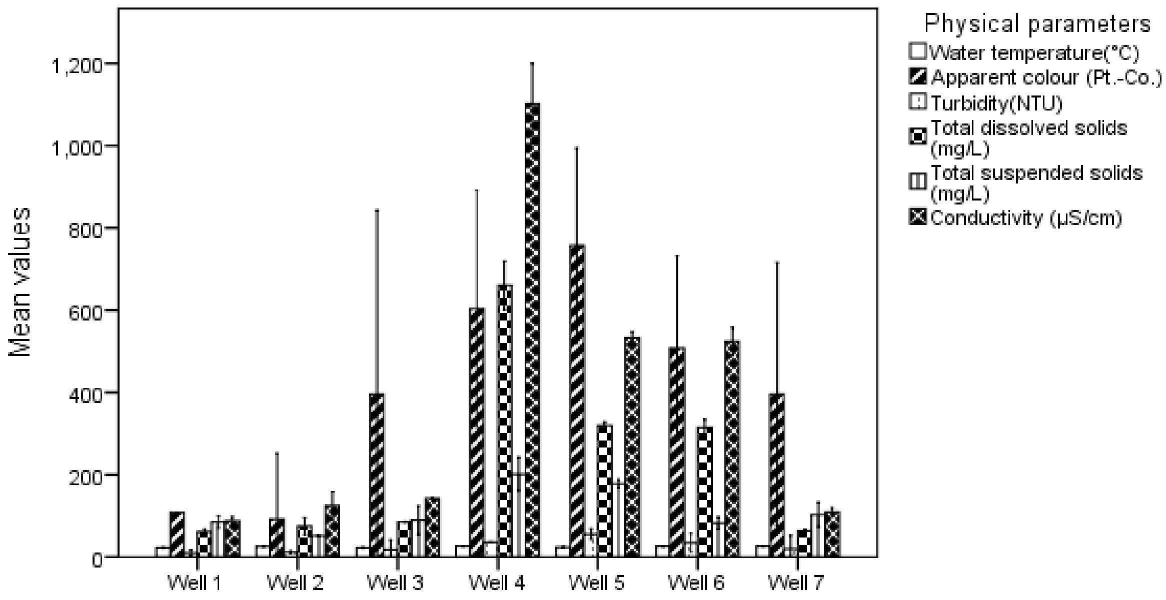

Figure 1a: Physical parameters of well water in wet season

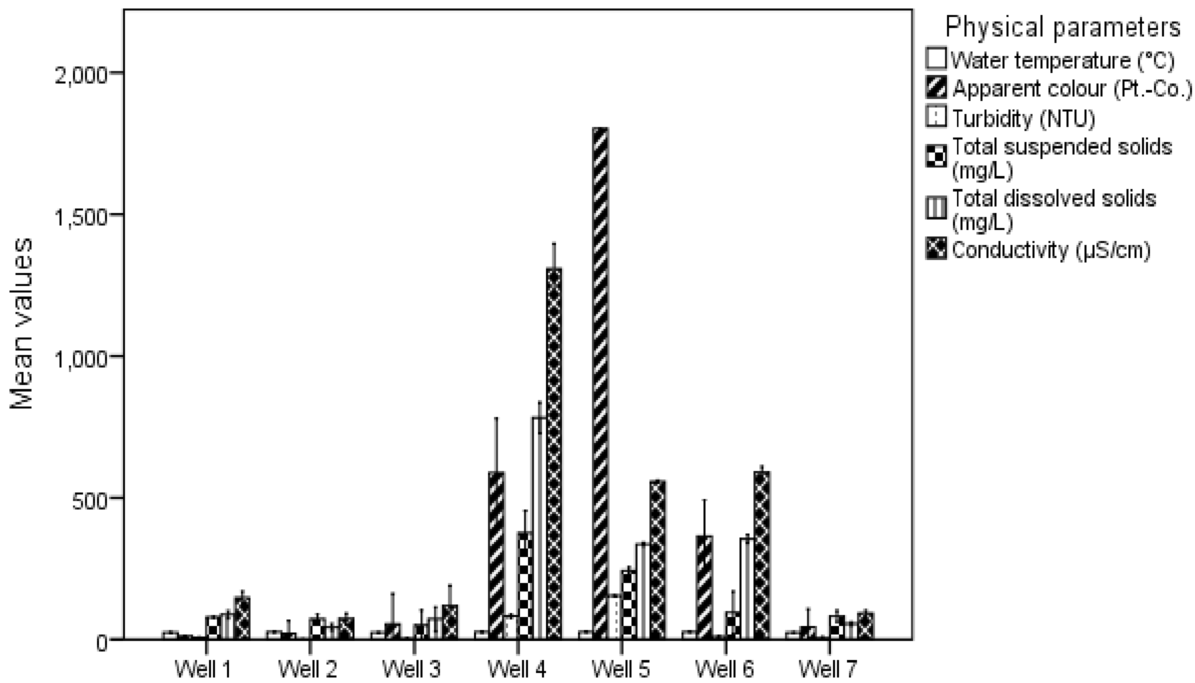

Figure 1b: Physical parameters of well water in dry season

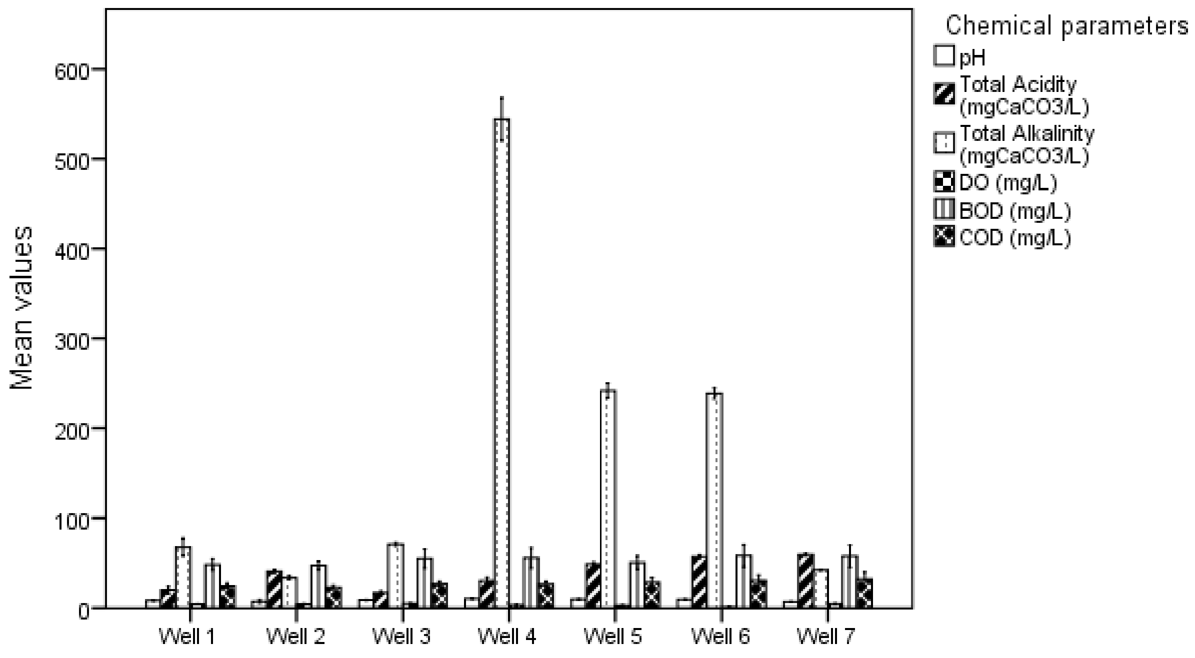

Figure 2a: Chemical parameters of well water in wet season

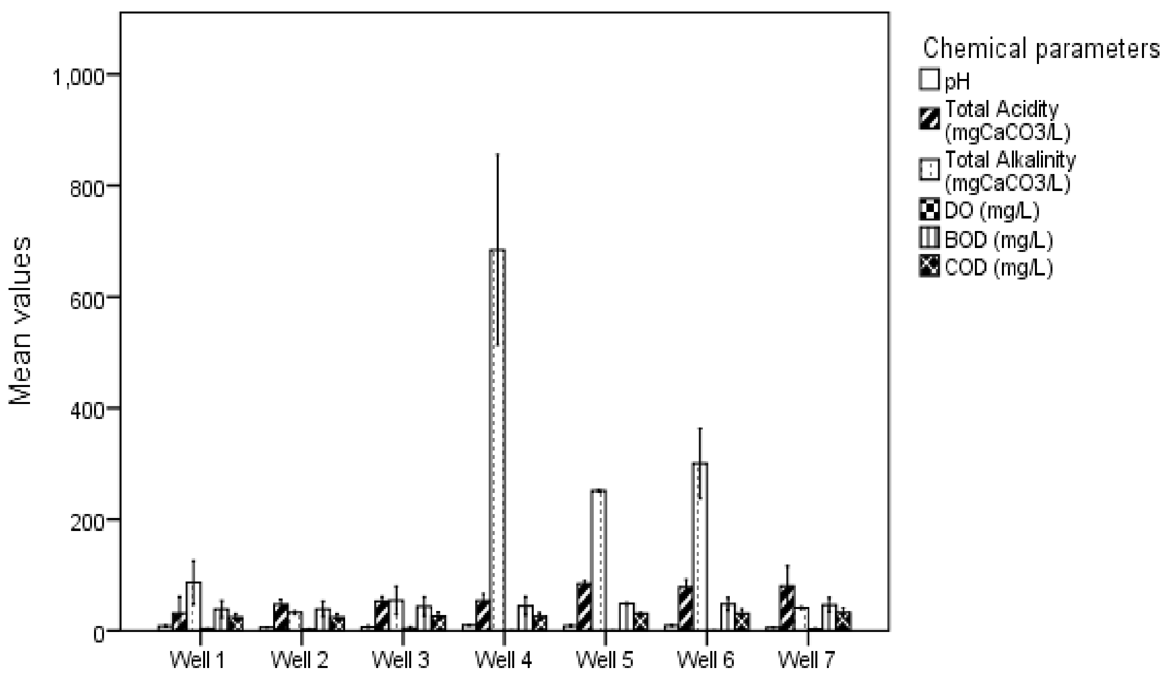

Figure 2b: Chemical parameters of the well water in dry season

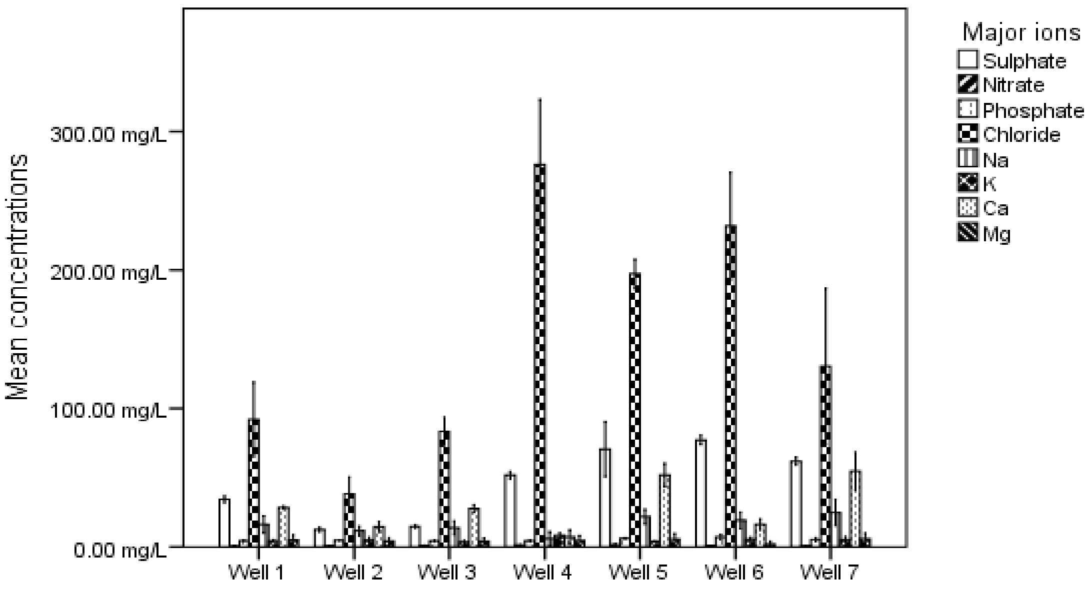

Figure 3a: Major ions of well water samples in the wet season

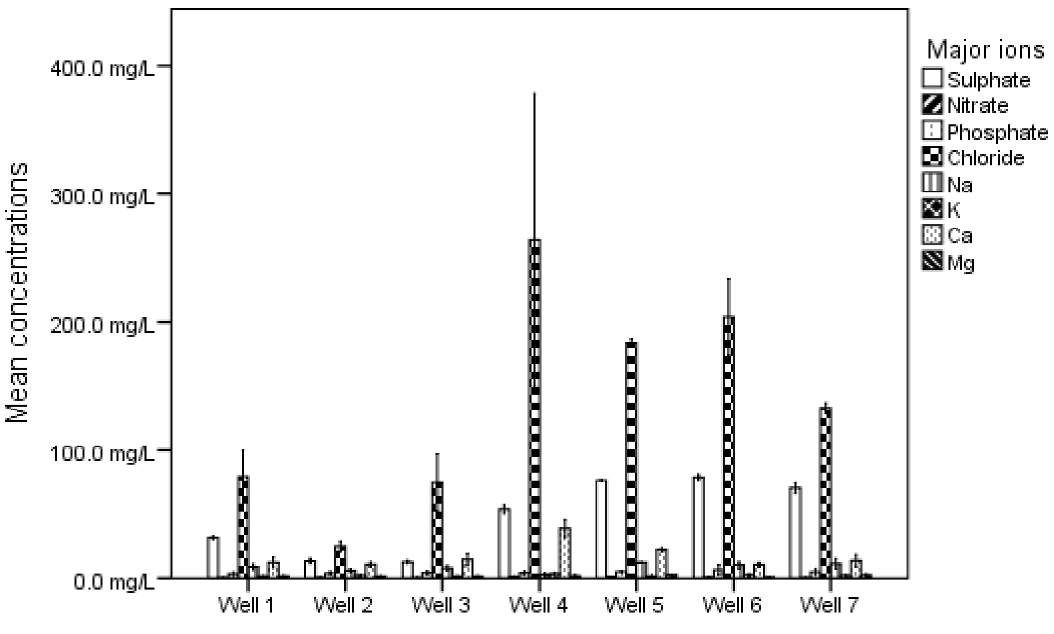

Figure 3b: Major ions of well water samples in the dry season

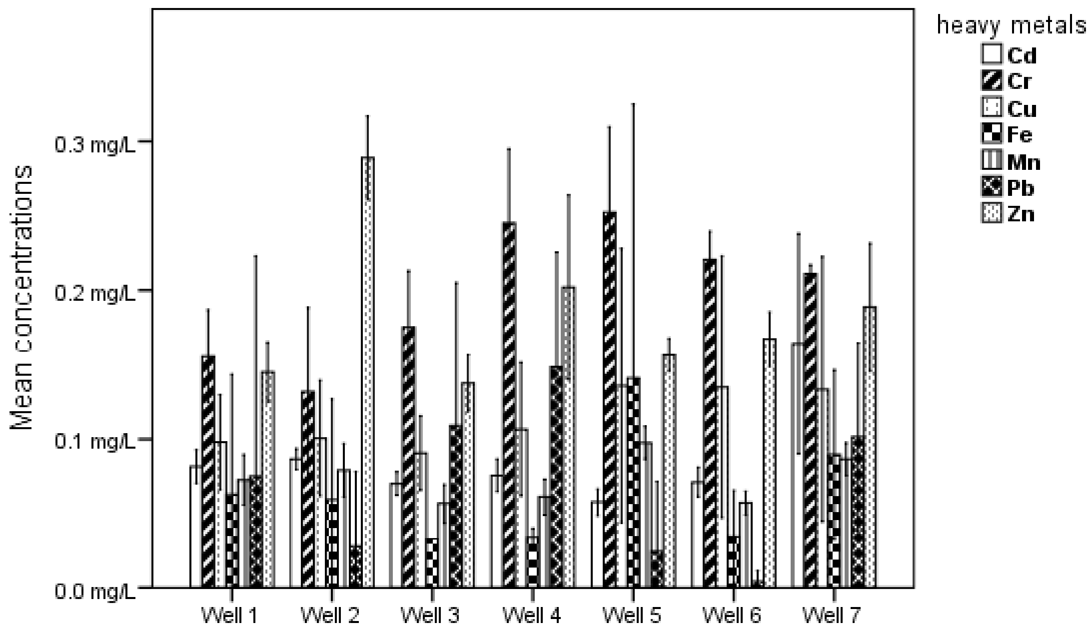

Figure 4a: Heavy metal concentrations of well water in wet season

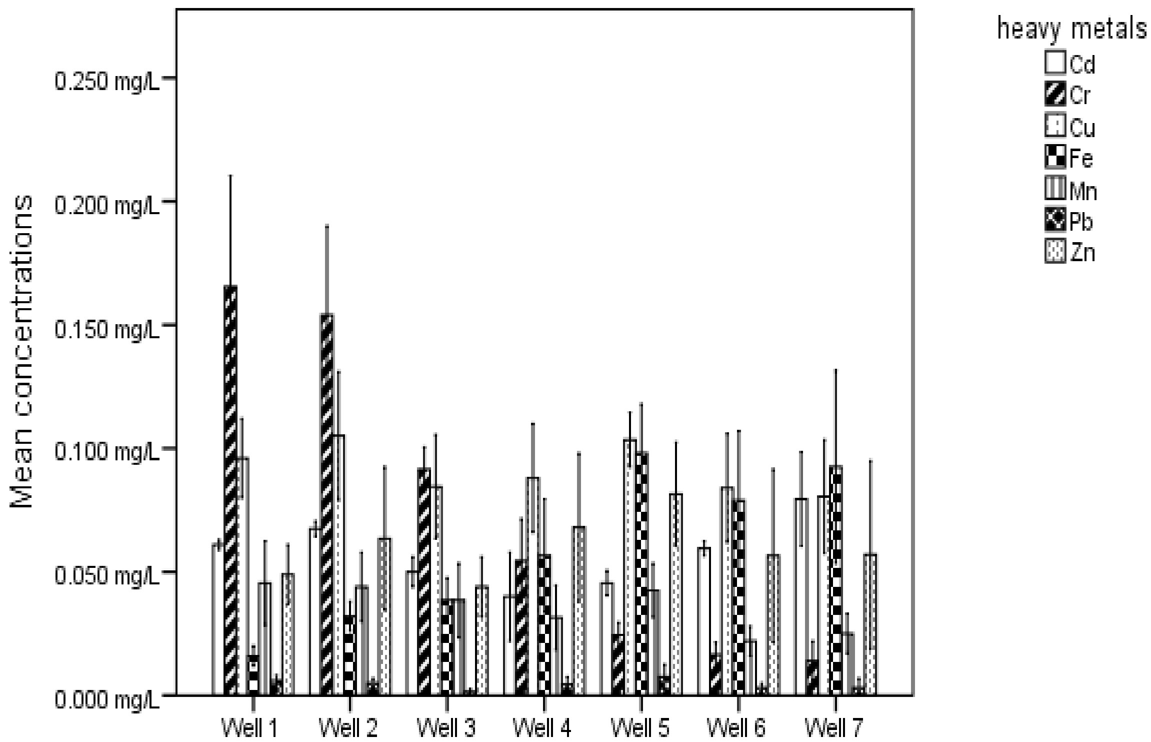

Figure 4b: Heavy metal concentrations of well water in dry season