Available online at www.worldscientificnews.com

World Scientific News

An International Scientific Journal

WSN 111 (2018) 100-110 EISSN 2392-2192

Bacteriological quality assessment of two sources of water supplies in Mubi, North-eastern Nigeria

M. Y. Tula*, G. A. Onyeje and **A. John**

Department of Biological Science Technology, Federal Polytechnic Mubi, Adamawa State, Nigeria

*E-mail address: birtyty@gmail.com

ABSTRACT

Water is essential for all life forms and the provision of safe drinking water to the populace cannot be overemphasized. This study examined the bacteriological quality of two sources of water supplies in Mubi, North-eastern Nigeria. A total of 72 water samples were analysed. These include 30 from 10 brands of sachet water and 42 from 21 boreholes in seven different wards of Mubi. Heterotrophic plate count (HPC) was determined by pour plate technique and the total coliform count was determined by 3-3-3 regimen using most probable number (MPN) technique. *Escherichia coli* and other isolates were identified by standard protocols. The mean HPC for both borehole and sachet water samples were variable and ranged from $3.3 \times 10^2 – 4.7 \times 10^4$ cfu/ml for sachet water and $1.1 – 6.0 \times 10^4$ cfu/ml for borehole water samples. The HPC of borehole water samples were significantly higher than those of sachet water (P = 0.006). The results showed that the mean MPN index for sachet water samples from brand HCM, KGN, OYM and YNS were zero (0). Brand UDS had the highest mean MPN index (1966.7), while other brands had low mean MPN index that ranged from 3.0 -9.1. In the same vein, the mean MPN index of borehole water samples were high, variable and ranged from 3.7 – 1750. Statistically, the mean MPN index/100ml of borehole water samples were significantly higher than those of sachet water samples (P = 0.006). A total of 49 non-repetitive bacterial species were isolated from the two sources of water. These include *E. coli* (30), *Enterobacter* spp (3), *P. aeruginosa* (5) and *Citrobacter* spp (11). The distributions of bacterial isolates from the two sources of water showed that *E. coli* was detected in two brands of sachet water SDK and DYJ and 20 representative boreholes in all the locations, while other organisms were variably distributed. The presence of these organisms constitutes public health significance.

***Keywords*:** Bacteriological, water supplies, Mubi, Coliform, Heterotrophic plate count

(Received 08 September 2018; Accepted 24 September 2018; Date of Publication 25 September 2018)

1. INTRODUCTION

Water is a basic necessity for life, needed by all forms of life including plants and animals as such a good supply of drinking water must be available to all consumers [1]. Its provision and availability is a fundamental right of every individual in a community. The availability and accessibility of clean portable water is a major concern of people living in developing countries despite the fact that water occupies 70% of the earth [2].

The inability of government to meet the ever increasing water demand, many peri-urban communities and rural areas in Nigeria resort to alternative sources of water such as wells and borehole for drinking and other domestic activities. This is imperative because pipe-borne water is not available; where available, its supply is rather erratic. Generally speaking, groundwater supplies were believed to be of good quality due to the natural filtering ability of the substrata environment [3], but the quality can deteriorate due to poor resource management and inadequate source of protection.

Currently, the available underground water sources especially in developing countries are becoming polluted due to the increasing growth in human population, industrialization, indiscriminate refuse dumpsites, and climate change [4]. Reports from previous research works showed that majority of hand dug wells and borehole waters in Nigerian communities were microbiologically poor [4-8]. Consequently, the populace are faced with the risk of waterborne diseases.

Globally, about 80% of all diseases and death in developing countries are water-related as a result of polluted water [9]. The numbers of water-borne disease outbreaks that have been reported in Nigeria demonstrate that transmission of pathogens by drinking water remains a significant cause of illness [10, 24-31].

1. 1. Status of water supplies in Mubi

In about two decades, there was no supply of pipe-borne water in Mubi. Infact, the facilities for such, had deteriorated and are no longer in place. Hence, people in Mubi largely depend on other sources of water for drinking and other domestic purposes. One of such water source is borehole.

A borehole is a hydraulic structure which when properly designed and constructed permits the economic withdrawals of water from aquifer [11]. The water serves as the major source of drinking water not only in Mubi but also in the local population of Nigeria. Borehole water in Mubi metropolis is virtually vended in 20-251 gallon carried on hand push truck or open vans and water tankers. However, the major concern is that most of these boreholes were cited in unhygienic areas, closer to refuse dump sites (Fig. 1)

Another source of drinking water in Mubi is sachet water popularly known as ‘pure water’. The production, marketing and consumption of sachet water in Mubi have increased tremendously over the years with several brands being marketed. The perception is that water in sachet is pure and devoid of any contaminating indices. However, several reports showed that majority of water in sachet were of poor microbiological quality [3, 12-14].

Fig. 1. One of the borehole locations with huge heaps of refuse

1. 2. Standard Guidelines for drinking water

Whichever and wherever the source of the water, The WHO standards state that drinking water should not contain any micro-organisms known to be pathogenic or any bacteria indicative of faecal pollution [15] or total coliform [14]. *Citrobacter*, *Enterobacter*, *Esherichia* and *Klebsiella* are the four genera of the Enterobacteriaceae family that constitute the coliform bacteria. From these genera, *E. coli* is generally used as indicator of faecal pollution of water samples. This was based on the fact that *E. coli* is abundant in human and animal faeces and is not usually found in other niches, and could be easily detected by its ability to ferment lactose.

Therefore, this study was carried out to evaluate the bacteriological quality of two sources (Borehole water and some sachet water) of water within Mubi and its environs and to highlight its safety and portability based on local and international guidelines.

2. MATERIALS AND METHODS

2. 1. Study area

Mubi metropolis is a geo-political area comprising of two local government areas; Mubi North and Mubi South. The metropolis is located between latitudes 10° 05' and 10° 30' N of the equator and between longitude 13° 12' and 13° 19' E of the Greenwich meridian.

The two Local government areas occupy a land area of 192,307 Km^2 and support a total population 260,009 people (National Population Census 2006). The area shares boundary with Maiha L.G.A in the South, Hong L.G.A in the West, Michika L.G.A and Cameroon Republic in the East. The major ethnic groups in Mubi includes; Fali, Gude, Kilba, Higgi, Margi and Nzanyi [16].

2. 2. Sample collection

A total of 72 water samples were collected and analysed for this study. Out of these, 30 were sachet water belonging to 10 brands (replicated three times) while 42 water samples were collected from 21 different boreholes located in seven wards in and around Mubi. These wards include Nassarawo, Dirbishi, Vimtim, Monuva, Kolere, Wuro-patuji and Sabonlayi. In each ward, three boreholes were chosen and their samples replicated two times.

The sachet water were coded as follows; OFR, HCM, SDK, KGN, AHS, DYJ, OYM, UDS, RNB and YNS. Samples were labelled and transported in ice packs to the laboratory and were analysed within 1-2 hrs after collection.

2. 3. Heterotrophic Plate Count

Total heterotrophic plate count (HPC) was obtained using the pour plate method. Ten fold serials dilutions of water samples were prepared in sterile peptone broth (Himedia) and 0.5 ml aliquots of each dilution was inoculated into 10 ml each of molten Nutrient Agar in universal bottles.

These were then thoroughly mixed poured into sterile Petri-dishes and incubated at 37 °C for 24 h. Petri-dishes from dilutions containing between 30 and 300 discrete colonies were counted and the result expressed as the numbers of colony per millilitre [17].

2. 4. Determination of total coliform count and *Escherichia coli*

The multiple tube fermentation technique was used for enumeration of total coliform [17]. MacConkey broth containing inverted durham tubes was used for presumptive test and the tubes incubated at 37 °C for 24h for the estimation of total coliforms. Eosin methylene blue (EMB) agar was used for the confirmatory test for the presence of *E. coli*. Organisms with green metallic sheen with dark centres were taken as positive for *E. coli*. Standard biochemical test were used to identify other organisms [18].

2. 5. Statistical analysis

Data were analyzed using IBM SPSS Statistics version 21 (Armonk, NY: IBM Corp). Descriptive statistics were used to summarise the HPC and MPN index of all the water samples. Continuous data were analyzed using the Mann–Whitney statistics test. An alpha level of less than or equal to 0.05 was used to determine statistical significance for all the data obtained.

3. RESULTS AND DISCUSSION

3. 1. Heterotrophic plate count of water samples

The mean HPC for both borehole and sachet water samples were variable and ranged from $3.3 \times 10^2 - 4.7 \times 10^4$ cfu/ml for sachet water and $1.1 - 6.0 \times 10^4$ cfu/ml for borehole water samples (Table 1 and 2). The HPC of borehole water samples were significantly higher than those of sachet water (P = 0.006).

Table 1. Mean Heterotrophic plate count (HPC) and most probable number (MPN) of sachet water samples

Brand Code	Mean HPC (cfu/ml)	Mean MPN index/100 ml
OFR	4.3×10^3	3
HCM	1.9×10^3	0
SDK	1.5×10^3	9.1
KGN	1.7×10^3	0
AHS	1.3×10^3	3
DYJ	3.3×10^2	3
OYM	3.3×10^2	0
UDS	4.7×10^4	1966.7
RNB	1.9×10^3	7.3
YNS	3.3×10^2	0
WHO	1.0×10^2	0
USEPA	1.0×10^2	0
SON	-	10

The heterotrophic group of bacteria encompass a broad range of bacteria that uses organic carbon sources to grow. Colony counts of heterotrophic bacteria, referred to as HPC, provide an indication of the general load of aerobic and facultative anaerobic bacteria of a water sample. The total heterotrophic plate counts (HPC) for all the water samples (both sachet and borehole) were generally high exceeding the limit recommended by both USEPA and WHO (of 1.0×10^2 cfu/ml), which is the standard limit of heterotrophic count for drinking water. Significant higher HPC in borehole water than sachet water was not unexpected. This is because sachet water undergoes treatment processes where as borehole water is raw from the source.

The high HPC above the standard limit in sachet water assayed was an index that the treatment processes was faulty, or the quality of the water source before the treatment was microbiologically poor [19]. It may also mean that the heterotrophic bacteria are resistant to disinfection [20]. The high HPC in borehole water may reflect poor qualities of the water source which may be due to contamination from human activities around the area the boreholes were cited. Higher HPC than the standard limit in sachet water calls for concern because water in sachet has already been processed and ready for consumption, whereas borehole water can be further processed before consumption. Although the majority of heterotrophic organisms do not present a health risk to immunocompetent individuals, some of the bacteria present may be opportunistic pathogens and can cause opportunistic infections in immunocompromised individuals [20]. The fact that there is no epidemiological evidence that higher HPC populations have any public health significance, lower HPC bacterial populations in drinking water are more preferable than higher HPC populations.

3. 2. Mean Total coliform count (cfu/ml)

The mean MPN index/100 ml of water samples were presented in Table 1 and 2 for sachet and borehole water samples respectively. The results showed that the mean MPN index for sachet water samples from brand HCM, KGN, OYM and YNS were zero (0). Brand UDS had the highest mean MPN index (1966.7), while other brands had low mean MPN index that ranged from 3.0 -9.1. In the same vein, the mean MPN index of borehole water samples were high, variable and ranged from 3.7 – 1750. Statistically, the mean MPN index/100 ml of borehole water samples were significantly higher than those of sachet water samples (P = 0.006).

Table 2. Mean Heterotrophic plate count (HPC) and most probable number (MPN) of Borehole water samples

Borehole Location	Mean HPC (CFU/ML)			Mean MPN index/100 ml		
	Borehole 1	Borehole 2	Borehole 3	Borehole 1	Borehole 2	Borehole 3
Nassarawo	3.3×10^4	3.4×10^4	4.7×10^4	1203.6	1203.7	552.2
Dirbishi	3.7×10^4	3.2×10^4	1.7×10^4	13.3	26.5	23.5
Vimtim	2.7×10^4	5.7×10^4	1.1×10^4	780.0	11.5	17.0
Monuva	2.9×10^4	6.0×10^4	1.9×10^4	3.7	15.5	9.1
Kolere	2.4×10^4	5.2×10^4	2.0×10^4	555.5	65.0	122.1
W/patuji	3.5×10^4	3.5×10^4	3.5×10^4	597.5	1232	1750
Sabonlayi	4.5×10^4	4.7×10^4	2.3×10^4	236.0	596.5	52.0
WHO	1.0×10^2	1.0×10^2	1.0×10^2	0	0	0
USEPA	1.0×10^2	1.0×10^2	1.0×10^2	0	0	0
SON	-	-	-	10	10	10

Absence of total coliform and *E. coli* in four brands of sachet water (HCM, KGN, OYM and YNS) conforms to the guidelines of USEPA and WHO for drinking water [15] which states that water meant for drinking should not contain faecal coliform or *E. coli* and ideally there should be no total coliform. This implies that the batches of these brands of sachet water analysed were of higher microbiological grade and therefore suitable for drinking. This could be attributed to the total adherence to strict quality assurance procedures in the laboratory and production premises of the companies concerned.

However, the non-detection of *E. coli* does not guarantee that these brands of sachet water were completely safe because the water samples analysed were only a snapshot of the water being distributed within Mubi metropolis. Moreover, *E. coli* and other coliforms in general are more sensitive to disinfection than more chlorine-resistant pathogens such as viruses and *Cryptosporidium* oocysts [20]; including other protozoa and helminthes which are now increasingly transmitted through drinking water [14]. Brands of sachet water with coliform count less than 10 and absence of *E. coli* (OFR, AHS and RNB) conform to the guidelines of Standard organisation of Nigeria (SON) [21] and therefore may be suitable or fit for drinking. However, these same brands may not be fit for drinking when international guidelines for drinking water were applied.

The presence of *E. coli* in brands SDK and DYJ was a reflection of poor sanitary condition of the water samples and also faecal contamination. Consequently, undermine the suitability of the brands for human consumption. This may be due to ineffectiveness or malfunctioning of the treatment process employed. According to Edberg [22], no treatment process or method used in mass production of drinking water yields a sterile product; it only produces a safe product devoid of pathogenic organisms. Also, detection of organism indicator of faecal contamination in these brands of sachet water emphasize the need for continuing implementation of the several laws promulgated by National Agency for Drug Administration and Control (NAFDAC) in Nigeria, and continuous monitoring to increase reduction in the sales of contaminated brands of sachet water.

The high number of total coliform bacteria and the presence of *E. coli* in all the boreholes (with the exception of one borehole from Dirbishi) were indices of poor sanitary conditions around the boreholes and possible recent contamination with faecal materials. The finding of this study was not unexpected considering the fact that most of these boreholes were cited in unhygienic and poor sanitary areas (see figure 1). Our findings also collaborated with earlier report which showed that underground water is often considered as the purest form of water. However, it's susceptibility to contamination could be due to improper construction, animal waste, proximity to toilet facilities, sewage, refuse dump site and various human activities surrounding it [23]. Another factor that could have led to high coliform count and the indicator of recent faecal contamination could be that the boreholes were used for a very long period of time. This may lead to deterioration of the water quality because the pipes sunk underground may have been corroded, with random cracks and perforations, which may allow passage of contaminated water containing potential pathogens into the main water body.

3. 3. Frequency of *E. coli* and other Bacterial genera

A total of 49 non-repetitive bacterial species were isolated from the two sources of water. These include *Escherichia coli* (30), *Enterobacter* spp (3), *P. aeruginosa* (5) and *Citrobacter* spp (11). The distributions of bacterial isolates from the two sources of water

showed that *E. coli* was detected in two brands of sachet water (SDK and DYJ) and 20 representative boreholes in all the locations (Table 3).

Table 3. Distribution of bacterial species isolated from the two sources of water.

Brand code/Borehole location	*E. coli*	*Enterobacter* spp	*P. aeruginosa*	*Citrobacter* spp
OFR	-	-	1	-
HCM	-	-	-	-
SDK	1	-	1	-
KGN	-	-	-	-
AHS	-	1	-	-
DYJ	1	-	-	-
OYM	-	-	-	-
UDS	-		-	1
RNB	-	-	1	-
YNS	-	-	-	-
Nassarawo	4	1	-	1
Dirbishi	2	-	1	3
Vimtim	5	-	-	1
Monuva	3	-	1	2
Kolere	5	1	-	-
Wuro-patuji	4	-	-	2
Sabonlayi	5	-	-	1
Total	30(61.2)	3(6.1)	5(10.2)	11(22.5)

Most of the boreholes sampled are used for commercial purposes and because pipe-borne water is not available, people in Mubi largely depends on this water sources for drinking and other domestic activities. Therefore, the presence of bacterial isolates such as *E. coli*, *Enterobacter* spp, *Citrobacter* spp and *Pseudomonas aeruginosa* in both sachet and borehole water is of public health significance. As earlier mentioned, the presence of *E. coli* in water is nearly always associated with recent faecal pollution. Faeces can also be a source

of pathogenic viruses, protozoa and helminthes which are associated with water-borne diseases. All the bacterial isolates encountered are Gram negative and members of the family Enterobacteriaceae (except *P. aeruginosa*). They can cause illness such as watery and bloody diarrhoea, dysentery, urinary tract infections and when introduced into the bloodstream, they can lead to bacteremia [1]. Moreover, taste, odour and turbidity in water are usually linked to the presence of *P. aeruginosa* [14]. The presence of these bacterial species in water samples assayed may possibly imply the presence of pathogens that may cause acute intestinal illnesses, which are generally considered discomfort to health and could become fatal for some vulnerable groups such as children and immunocompromised individuals. Studies have shown that about 80% of sicknesses and deaths among children worldwide have been associated with the consumption of unsafe water [15].

4. CONCLUSIONS

This study highlighted the bacteriological quality of both sachet and borehole water in Mubi, North-eastern Nigeria. Although some of the sachet water were examined to meet both local and international guidelines for drinking water, others and most borehole water fall short of these standards. Therefore, periodic microbiological assessment of drinking with the regulatory body to forestall and maintain good quality assurance in line with internationally defined drinking water standards is paramount. This will go a long way to protect the health of the public and ensure that water is safe for public use. Also, dumping of refuse around boreholes should be discourage and citing of boreholes closer to sources of contamination should be prohibited or discourage.

Acknowledgment

This work was supported by the Tertiary Education Trust Fund (TETFUND) of Nigeria (2011-2014 merged). Authors are therefore grateful.

References

[1] Obioma A, Chikanka AT, Loveth, NW. Evaluation of Bacteriological Quality of Surface, Well, Borehole and River Water in Khana Local Government Area of Rivers State, Niger Delta. *Annals Clin. Lab. Res.* 2017; 5(3): 183.

[2] Eboh JO, Ogu GI, Idara MU. Microbiological Quality of Borehole and Well Water Sources In Amai Kingdom, Ukwuani Local Government Area Of Delta State, Nigeria. *Intl. J. Adv. Acad. Res. Sci. Tech. Eng.* 2017; 3(7): 17-28

[3] Esi A, Samuel FG, Helen KA, Agnes A. Microbial Quality of Sachet and Bagged Drinking Water: A Case Study in Kumasi, Ghana. *Res. J. Microbiol.* 2014; 9: 199-207.

[4] Hati SS, Dimari GA, Ngueadoum N. Quality status of drinking water sources in Gombe Metropolis of Nigeria. *Amer. J. Sci. Indust. Res.* 2011; 2(4): 537-42.

[5] Ibe SN, Okplenye JI. Bacteriological analysis of Borehole water in Uli, Nigeria. *Afr. J. Appl. Zool. Environ. Biol.* 2005; 7: 116-19.

[6] Lateef A, Kolawole LL, Agosu SO. Quality Assessment of Some Groundwater Samples in *Ogbomoso* Metropolis, Southwest Nigeria. *J. Environ. Earth Sci.* 2012; 2(6): 39-47.

[7] Amenu D. Bacteriological and Physicochemical Quality of Well Water Sources. *Res. J. Chem. Environ. Sci.* 2014; 2 (5): 13-27.

[8] Aboh EA, Giwa FJ, Giwa A. Microbiological assessment of well waters in Samaru, Zaria, Kaduna, State, Nigeria. *Ann. Afr. Med.* 2015; 14: 32-38.

[9] Ayeni AO, Balogun II, Soneye ASO. Seasonal assessment of physico chemical concentration of polluted urban river: case of Ala River in South-western Nigeria. *Res. J. Environ. Sci.* 2011; 5(1): 22-33.

[10] Nwidu LL, Oveh B, Okorioye T, Vaikosen NA. Assessment of the water quality and prevalence of water-borne diseases in Amassaoma, Niger Delta, Nigeria. *Afr. J. Biotechnol.* 2008; 7(17): 2993-2997.

[11] Akpoveta O, Okoh B, Osakwe S. Quality assessment of borehole water used in the vicinities of Benin, Edo State and Agbor, Delta State of Nigeria. *Curr. Res. Chem.* 2011; 3(1): 62-9.

[12] Ekwunife CA, Okafor SO, Ukaga CN, Ozumba NA, Eneanya CI. Parasites associated with sachet drinking water (Pure water) in Awka, South‑Eastern Nigeria. Sierra Leone *J. Biomed. Res.* 2010; 2: 22-27

[13] Oyedeji O, Olutiola PO, Moninuola MA. Microbiological quality of packaged drinking water brands marketed in Ibadan metropolis and Ile – Ife city in South Western Nigeria. *Afr. J. Microbiol. Res.* 2010; 4: 96‑102.

[14] Ugochukwu S, Giwa FJ, Giwa A. Bacteriological evaluation of sampled sachet water sold in Samaru-Zaria, Kaduna-State, Nigeria. *Nig J Basic Clin Sci* 2015; 12(1): 6-12.

[15] WHO. Guidelines for Drinking Water Quality, Incoporation into the First and Second Addenda. Recommendation. 3rd ed., Vol. 1. Geneva Switzerland: World Health Organisation. 2008, p. 121-26.

[16] Adebayo AA. Mubi Region: A geographic synthesis. Paraclete Publishers, Yola. 2014, 17–37.

[17] American Public Health Association (APHA). Standard Methods for the Examination of Water and Wastewater, 21st Edn. Washington, D.C., 2005.

[18] Washington CW, Stephen DA, Williams MJ, Elomer WK, Gary WP, Paul CS and Gail LW. Koneman's Colour Atlas and Textbook of Diagnostic Microbiology, 6th edn. Lippincott Williams and Wilkins, Philadelphia, USA., 2006.

[19] Bartram J, Cotruvo J, Exner M, Fricker C, Glasmacher A, editors. Heterotrophic counts and drinking-water safety: the significance of HPCs for water quality and human health. London, UK: IWA publishing; 2003. http://www.who.int/water_sanitation_health/dwq/hpc/en/index.html. Washington CW.

[20] Health Canada. Guidance on the Use of Heterotrophic Plate Counts in Canadian Drinking Water Supplies. Water, Air and Climate Change Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario, 2012. (Catalogue No. H144-6/2013E-PDF).

[21] SON. Nigerian standards for drinking water quality. ICS 13.060.20. 2007; pp. 1-30.

[22] Edberg SC. Assessing health risk in drinking water from naturally occurring Microbes. *J. Environ. Health,* 1996; 58(6): 18-24.

[23] Shittu OB, Olaitan JO, Amusa TS. Physico-Chemical and Bacteriological Analysis of Water Used for Drinking and Swimming Purpose. *Afr. J. Biochem. Res.* 2008; 11: 285-90.

[24] M. O. Jaji, O. Bamgbose, O. O. Odukoya, T. A. Arowol. Water quality assessment of Ogun river, South West Nigeria. *Environmental Monitoring and Assessment* October 2007, Volume 133, Issue 1–3, pp 473–482

[25] Ahonkhai, S. I., & Chukwuogo, E. I. (1996). Effects of industrial activities in Warri area on the surface water quality. *Environmental Monitoring and Assessment,* 16, 259–264.

[26] Calamari, D., & Naeve, H. (1987). Water quality problems in Africa: A brief report. *International Journal of Environmental Studies,* 29, 3–8.

[27] Ichikawa, H. (1990). Microbiological indicators for evaluating treatability on water purification process. *Japanese Journal of Water Pollution Research,* 13, 477–484.

[28] Mathuthu, A. S., Zaranyika, F. M., & Jonnalagadda, S. B. (1993). Monitoring of water quality in Upper Mukuvisi River in Harare, Zimbabwe. *Environment International,* 19, 51–61.

[29] Obire, O., Tamuno, D. C., & Wemedo, S. A. (2003). Physico-chemical quality of Elechi creek in Port Harcourt, Nigeria. *Journal of Applied Science & Environmental Management,* 7, 43–49.

[30] Vincent N. Chigor, Veronica J. Umoh, Charles A. Okuofu, Joseph B. Ameh, Etinosa O. Igbinosa, Anthony I. Okoh. Water quality assessment: surface water sources used for drinking and irrigation in Zaria, Nigeria are a public health hazard. *Environmental Monitoring and Assessment* May 2012, Volume 184, Issue 5, pp 3389–3400

[31] Ibiam Ntachiobi Ama, Godfry E. Nwajei, P. O. Agbaire, Distribution of Trace Elements in Surface Water and Sediments from Warri River in Warri, Delta State of Nigeria. *World News of Natural Sciences* 11 (2017) 65-82