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Full Length Research Paper

Effects of household wastes on surface and underground waters

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The impact of indiscriminate dumping of waste, particularly household wastes within certain locality in Ondo State, in the western part of Nigeria on the quality of surface water and underground water (that is, wells with rings and without rings) were investigated. The water was analyzed for some physico-chemical parameters and some heavy metals using the standard methods. The results show that wells without rings are more vulnerable to contaminants than those with rings – while the surface water and wells without rings recorded threatening values of health concern especially in Pb, Ni, and Cd where almost 100% of the samples analyzed exceeded the WHO and Nigeria Federal Ministry of Environment (FMENV) guidelines. Increased concentrations in some of the physico-chemical variables such as pH, turbidity, conductivity and phosphate above their permissible limit in water for domestic and other uses calls for urgent attention. The impact of the mineralogical nature of the sampling environment manifested in the concentration of some of the parameters. The study recommends proper monitoring of the entire localities.

Key words: pollution, contamination, wastes, heavy metals, groundwater, surface water.

INTRODUCTION

There has been an increasing concern about the environment in which man lives. Solid wastes, mount of rubbish, garbage and sewage are being produced everyday by our urban society. In an attempt to dispose of these materials, man has carelessly polluted the environment. In a traditional underdeveloped world, a fact that partly reflects the sampling locations considered in the present work, household wastes are completely biodegradable and homogenous. Consequently, both biodegradable and non-biodegradable materials now constitute household wastes. In the past, men thought the environment had an infinite capacity to devour his waste without any ill effects. More recently, however, man's health and welfare are being affected by environmental pollution.

These pollutants are substances present naturally in the environment but when released in significant amount by humans, become toxic.

The World Health Organization (WHO) estimates that more than 20% of the world population (around 1.3 billion people) has no safe drinking water and that more than 40% of all populations lack adequate sanitation (Oastridge and Trent, 1999). Poor water quality is still a significant problem in many parts of the world. It can often limit the use of these vital resources and in more extreme cases can harm human and other life (Forum and Entwicklung, 2001). Water can be polluted by substances that dissolve in it or by solid particles and insoluble liquid droplets that become suspended in it (Plant et al., 2001). Even paper is sometimes a high-tech material. It's not just a bunch of fibers that are laid down and put together. It's coated, bonded and got a tremendous amount of technology built in it (Stu Borman, 2002).

Many workers have detected elevated levels of both organic and inorganic pollutants and heavy metals in surface and underground water and water in the

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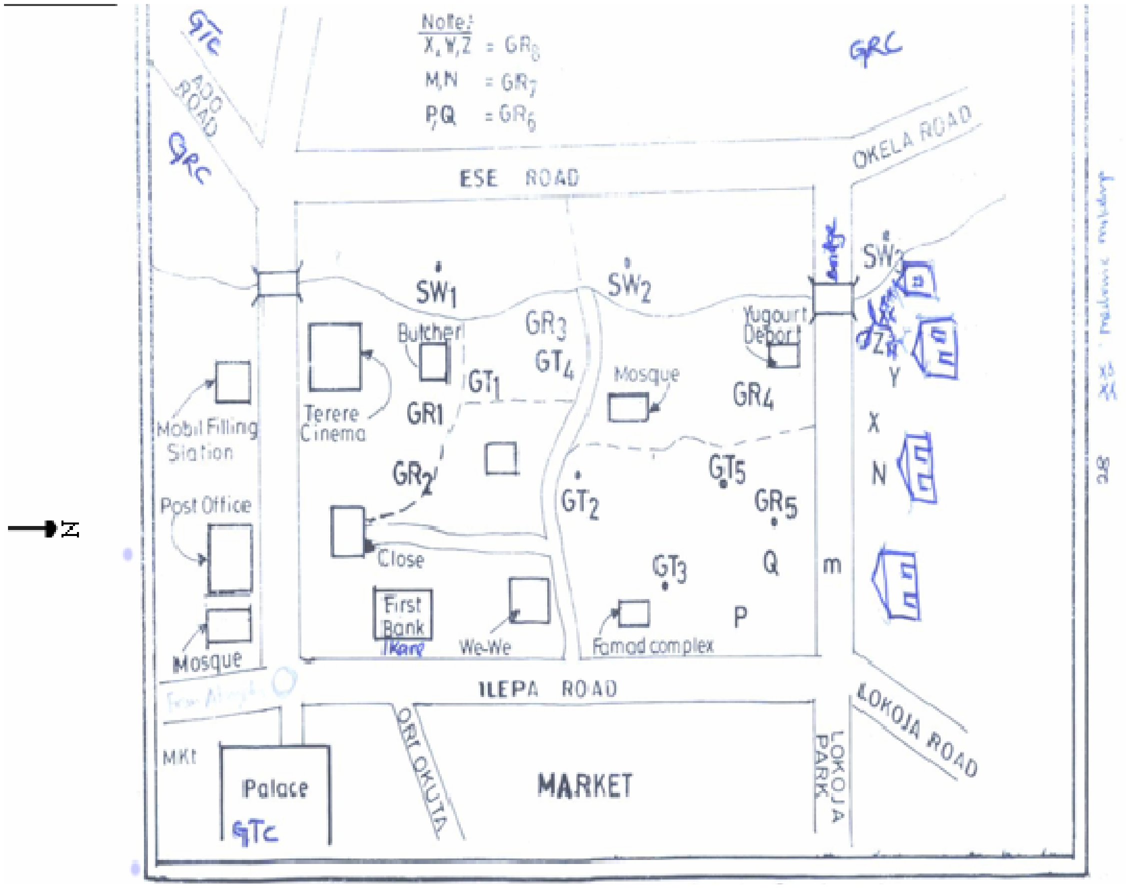

Figure 1. Sketch map of Ikare Central area showing the study points.

vicinity of solid waste landfills (van der Broek and Kirov, 1971; Murray 1981; Albaiges 1986; Borden and Yanoschak 1990). Generally, as a result of long retention time and natural filtering capacity of aquifers, groundwater is often unpolluted. However, leachates from wastes at a dump site, as observed in the present study, are potential sources of contamination of both groundwater and surface water (Odukoya et al., 2002). In addition, investigations have shown that in non-arid regions, infiltrations of water through landfill have caused water table molding. This causes leachate to flow downward and outward from the land fill. Downward flow pollutes ground-water while outward flow causes leachate springs at the periphery of the landfills or seepage into streams or other surface-water (Khanbilvardi et al., 1992).

Globally, people need to appreciate the fact that our environment is a delicately balanced substance and, indeed that it is a system. Consequently, the task of protecting it is not a regional issue, neither is it a continental affair. It goes beyond local initiates. But then, we have to start from somewhere. While thinking globally we must act locally. Thus, the research becomes necessary at the present location in Ikare-Akoko, Ondo state, Nigeria, where there is little or no awareness about the dangers inherent in contaminated water. It is all in an attempt to direct attention to issues of effective management of the environment and the protection of the water qualities therein.

STUDY AREA

This study was carried out at certain locations in Ondo state, in the western part of Nigeria (Figure 1). The only stream passing through this area now serves as a means for the inhabitants within and outside this location to dispose their wastes indiscriminately based on the throw away culture and a disposal method that reflects what could be referred to as ‘not-in my-backyard syndrome’. A critical assessment of the wastes at the present location shows the presence of plastics, bottles, metallic scraps, leather, iron, rubbers, pieces of clothes (rags), empty cans, bones and a lot of other materials. Several wells are situated around this location, some with rings (GR’s) and others without rings (GT’s). The butchery located around the surface stream (SW) also calls for concern for their direct dis-

Table 1. Some physico-chemical parameters of groundwater and surface water.

Sites	pH	EC mS/m	Turb. (NTU)	TS (mg/L)	TDS (mg/L)	SS (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	PO_4^{3-} (mg/L)	NO_3^- (mg/L)
GR-1	6.97	43.2	2.52	430	415	15	230	84	0.79	7.48
GR-2	7.04	28.4	2.25	200	180	20	206	84	0.47	7.40
GR-3	6.42	33.4	2.31	200	215	45	286	102	0.85	7.60
GR-4	6.93	51.8	2.19	410	386	24	304	130	0.57	8.80
GR-5	5.98	31.3	2.42	240	196	44	210	104	0.83	7.44
GR-6	6.92	26.9	2.13	230	174	36	202	75	0.78	7.48
GR-7	6.47	42.1	2.32	310	288	22	230	124	0.57	8.34
GR-8	5.84	37.0	2.47	270	254	16	234	88	0.84	7.76
GR-9	6.49	32.5	2.29	212	186	26	234	96	0.73	7.52
GR-10	6.39	27.1	2.10	226	210	16	228	93	0.64	7.46
Mean	6.54	35.4	2.30	273	250	26	236	98	0.71	7.73
GRC	6.23	27.3	1.21	115	102	13	126	96	0.36	5.2
GT-1	6.39	23.4	1.56	215	170	45	270	64	0.45	5.04
GT-2	6.37	24.9	1.59	220	188	32	240	67	0.41	4.40
GT-3	5.84	13.6	1.42	150	126	24	201	58	0.42	4.84
GT-4	6.44	23.2	1.49	250	230	20	284	54	0.47	5.36
GT-5	6.58	31.8	1.62	350	298	52	196	69	0.44	5.72
GT-6	6.38	15.7	1.32	213	192	21	221	61	0.41	4.90
GT-7	6.52	21.3	1.39	225	197	28	228	59	0.43	4.97
GT-8	6.57	22.6	1.60	196	174	22	199	53	0.43	5.15
GT-9	6.42	19.5	1.53	225	200	25	231	58	0.45	5.22
GT-10	6.41	21.1	1.23	219	185	34	217	62	0.43	4.52
Mean	6.39	21.7	1.48	226	196	30	229	61	0.43	5.01
GTC	7.02	12.4	1.11	130	115	15	74.2	72	0.27	4.60
SW-1	6.43	48.6	5.91	600	335	265	190	74	1.41	8.28
SW-2	7.24	43.4	3.62	580	320	240	154	63	1.37	8.13
SW-3	6.52	45.8	3.94	535	364	171	143	71	1.34	8.04
SW-4	6.59	45.9	3.74	574	334	240	159	69	1.39	8.11
Mean	6.79	45.9	4.30	572	338	229	161	69	1.38	8.14
SWC	6.47	52.6	1.49	420	215	205	42.0	67	0.51	4.20

GTs = wells with rings; GRC = wells with rings (control); GRs = wells without rings; GTC = wells without rings (control); SW = surface water; SWC = surface water (control).

charge of wastes into the stream. Control locations within the geographical location were equally assessed in order to compare data's obtained.

MATERIALS AND METHODS

Sampling and sample preparation

The sampling was carried out in October, 2006. Sampling points were chosen with the aim of collecting water samples at a place that truly represents the water body (Wilde et al., 1999). Twenty four (24) representative sites (Figure 1.0) were considered. Three other locations were considered as control, one representing each of the sampling source type. Grab-samples of surface water were collected using acid-washed plastic kegs. Underground water was collected using pre-cleaned bottles to which a rope was attached. In both cases, an air space equivalent to 1% of the container was left to allow for thermal expansion. Parameters like pH, conductivities and turbidities were determined in the field using calibrated Hannah pH meter, conductivity and turbidity meter respectively. About 100 ml of each sample were acidified with 0.2 ml of concentrated H_2SO_4 and later analyzed for metals. The rest samples were stored in the refrigerator at a temperature of about 4℃ prior to the analysis (American Public Health Association (APHA), 1989; Campolo et al., 2002).

Chemical analysis

The physico-chemical parameters observed in this study were determined using the standard methods (APHA, 1989). The chloride and sulphate were determined using the Mohr's and turbidimetric methods respectively. For the nitrate and phosphate, the cadmium reduction method and ascorbic acid method were employed respectively. Others like total solids (TS), total dissolved solids (TDS), pH, conductivities and turbidities were also determined accordingly. The heavy metals (Cd, Cu, Ni, Pb and Zn) were analysed using an atomic absorption spectrophotometer (Alpha 4AAS, Chemical Tech. Analytical, Euro) after careful digestions with concentrated HCl based on standard method. Results were later subjected to statistical analysis. Details of the recovery data show that Ni has the highest percentage recovery of 92.4%. Others (%recovery in bracket) gave Cd (83.3%); Cu (77.9%); Pb (80.6%) and Zn (87.5%). The statistical analysis consists of determining correlation coefficients (r = values) between the metals concentrations and some of the physico-chemical characteristics. It also involves comparing the mean from the three water sources.

RESULTS AND DISCUSSIONS

Quality parameters and nutrients

Details of the results of some physico-chemical parameters determined in the water from the various sources are presented Table 1. The pH of water from GR's ranged from 5.84 – 7.04 while for those from GT's ranged from 5.84 – 6.57. For samples from SW's the pH ranged from 6.43 – 7.24. The pH remains relatively within a close range throughout the sampling points indicating that changes in the concentration of other parameters cannot be totally associated to it. In Nigeria, the (Federal Environmental Protection Agency/Federal Ministry of Environment (FEPA/FMENV) effluent limit for pH in water for domestic use is 6.0 – 9.0 while the WHO maximum permissible limit for drinking water is 6.5 – 8.5 (FEPA/FMENV,1991; World Health Organization (WHO),1993; Natural Environment Management Authority(NEMA), 2003). Based on the guidelines, the pH of the entire sampling location would not adversely affect its use for domestic uses and recreational purposes.

The conductivity (EC) (in mS/m) ranges from 26.9 – 51.8, 13.6 – 31.8 and 43.4 – 48.6 for GR's, GT's and SW's respectively. The FEPA/FMENV limit for EC in domestic water supply is 20 mS/m (FEPA/FMENV, 1991; NEMA,2003). This limit was exceeded in all the water samples except in one location (13.6 mS/m) in water from GR's. Consequently, the parameter does give concern as it renders the water unsuitable for domestic use. The increased EC level may be due to effluents resulting from the various wastes coupled with the rocky nature of the terrain.

The turbidity (in NTU) levels ranged from 2.1 – 2.5, 1.2 – 1.6 and 3.6 – 5.9 for water from GR's, GT's and SW's respectively. These values though assumed very low, exceeded the turbidity limit of 0 to 1.0 NTU for domestic use. The elevated levels above the permissible limit may be associated with the turbulent water flow due to heavy rains during the sampling period. This turbid nature is not good for water as it allows for microbial contamination which can cause significant damage to humans and animals. Moreover, turbid water is more expensive to treat.

The total solids (TS) ranged (in mg/L) from 200 – 430, 150 – 350 and 535 – 600 in water from GR's, GT's and SW's respectively. There are significant differences in the individual water that make up a composite for a sample location. Apart from one location at site GT-5 (350 mg/L), the TS in water from other GT's are relatively close (Table 1). The same can also be said about water from GR's to a very large extent. In a similar manner, the TDS ranged from 174 – 415, 126 – 298 and 320 – 364 mg/L in water from GR's, GT's and SW's respectively. Based on WHO (1993) and FEPA/FMENV (1991) maximum permissible limit of 500 mg/L and 2,000 mg/L respectively for TS and a limit of 1,000 mg/L for TDS, the concentrations of TS and TDS in the present study does not call for any adverse effects when used for domestic and recreational purposes.

This mean phosphate levels (in mg/L as PO_4^{3-}) ranged from 0.47 – 0.85, 0.41 – 0.47 and 1.34 – 1.41 in water from GR's, GT's and SW's respectively. In Nigeria, the maximum permissible limit for phosphate as P in water system that will reduce the likelihood of algae growth is < 5 mg/L (FEPA/FMENV, 1991). The water samples from GR's and SW's all recorded 100% in excess of the WHO (1993) maximum allowable concentrations (0.5 mg/L). In fact, levels as high as 0.035 mg P/L has been reported to cause eutrophication-related problems in temperate zones (Rast and Thornton, 1996). Therefore, considering the levels reported in the present study, eutrophication may be a problem especially during treatment as filter clogging may occur (Murray et al., 2000).

In addition, the growth of blue-green algae could release toxic substances (cyanotoxins) into the water system (Holdsworth, 1991). The elevated level in surface water may be due to the releases from wastes of diverse composition into the flowing stream. The phosphate levels are far below the 20 – 80 mg P/L and 142 – 180 mg P/L as reported by other authors (Osibanjo and Adie, 2007). However, these studies were carried out within areas that receive heavy effluent from abattoir.

The concentration (in mg/L) of nitrate ranged from 7.40 – 8.80, 4.40 – 5.72 and 8.04 – 10.2 in water from GR's, GT's and SW's respectively. The concentration of nitrate in water samples depends on the nitrification activities of micro-organisms. The levels obtained in the study were far less than the FEPA/FMENV (1991) limit of 20 mg/L. Consequently, no adverse effects such a cyanosis as reported by some author is expected (IRDC, 1991).Chloride and sulphate were reported at a much higher concentrations than phosphate and nitrate. The concentrations (in mg/L) of chloride ranged from 202 – 304, 201 – 284 and 143 –190 in water from GR's, GT's and SW's respectively.

For sulphate, the ranges were 75 – 130, 54 – 69 and

Table 2. Range and mean concentrations of metals in groundwater and surface and surface water (mg/L).

Sample sources		Pb	Ni	Cu	Zn	Cd
GR - samples	Mean	1.23	0.44	0.024	0.21	0.22
(n = 10)	Max.	2.79	0.81	0.031	0.488	0.58
	Min.	0.23	0.12	0.005	0.041	0.01
	Std. Dev.	0.87	0.19	0.019	0.140	0.20
GT - samples	Mean	0.15	0.27	0.007	0.041	0.10
(n = 10)	Max.	0.86	0.61	0.028	0.088	0.26
	Min.	nd	0.10	0.001	0.001	nd
	Std. Dev.	0.28	0.15	0.088	0.031	0.09
SW - samples	Mean	5.24	0.41	0.022	0.12	0.400
(n = 4)	Max.	6.74	0.54	0.036	0.19	0.521
	Min.	5.26	0.43	0.013	0.11	0.411
	Std. Dev.	1.71	0.16	0.011	0.05	0.161

GT = wells with rings; GR = wells without rings; SW = surface water; nd = not detected.

63 – 71 mg/L respectively. In Nigeria, the maximum permissible limit for both chloride and phosphate in drinking water is 250 mg/L (FEPA/FMENV, 1991). None of the water samples from all the locations exceeded the sulphate permissible limit. However, about 16% of the total water sampled exceeded the chloride permissible limit. It must however be noted that most of the chloride concentrations, especially in water from wells (with/without rings) occur at concentrations > 200 mg/L. Though the levels are lower than the toxic limit (250 mg/L), they are equally of concern. The elevated level over phosphate and nitrate may be related to the nature of these sites which are rocky and suspected to contain some chloride mineral salts. Though values obtained in this report are lower than the toxic limit, if the trend should continue this way, water from this source would soon become hard. This of course, is of no economic value. At the moment, the levels of chloride and sulphate are normal for domestic use.

Metal variation across sampling locations

A summary statistics of the five heavy metals, cadmium (Cd); copper (Cu) lead (Pb), nickel (Ni) and zinc (Zn) determined in this study is presented in Table 2. The trends across the various sampling sources are indicated in Figures 2 (A – C). The mean concentration (in mg/L) of Pb, Cu, Ni, Zn and Cd in water from wells without rings (wells with rings in brackets) are 1.23 (0.15), 0.024 (0.007), 0.44 (0.27), 0.21 (0.04) and 0.22 (0.10) respectively. For the surface water, the mean concentrations (in mg/L) were 5.24, 0.022, 0.41, 0.12 and 0.400 for Pb, Cu, Ni, Zn and Cd respectively. The data in Figure 2 (A-C) show that highest concentrations of all the metals occurred in water from the surface stream. This is particularly of concern due to the strategic location of the stream and its usage in diverse forms by both human and domestic animals. The elevated level of metals in the surface water further implicates the magnitude of metal input from effluent/leacheates resulting from wastes which are indiscriminately dumped into the stream. In fact, significant mean difference were found ($p<0.05$) between levels of Pb (0.002), Cu (0.003), Ni (0.000), Zn (0.00) and Cd (0.007) in water from wells without rings. The pattern is similar for GT's and SW's except for Pb (0.140) in wells containing rings.

The level of Pb in the study is high and calls for concern. This is based on the fact that all the water samples except for about 50% of samples from GT's exceeded the WHO maximum permissible limit of 0.01mg/L (WHO, 1993). In Nigeria, the maximum permissible limit for Pb is 0.05mg/L. Considering the national guidelines, all the water from GR's and SW's significantly exceeded the tolerable limits along with only 10% of samples of water from GT's. Thus, adverse effects of Pb pollution may result from domestic use of the water and its use for livestock and aquaculture with guidelines of 0 - 0.1 and 0 - 0.01 mg/L respectively. Lead toxicity studies conducted on female animals revealed mostly miscarriages and potent mortality (Taupean et al., 2001). Comparing with a study, where a concentration of 0.1 mg/L had resulted in the development of neurological problem in fetuses and children (Fatoki et al., 2002), the results obtained in this study definitely require urgent attention. Nickel occurs at elevated concentrations in the study. This may be due to its presence in wastes of diverse forms

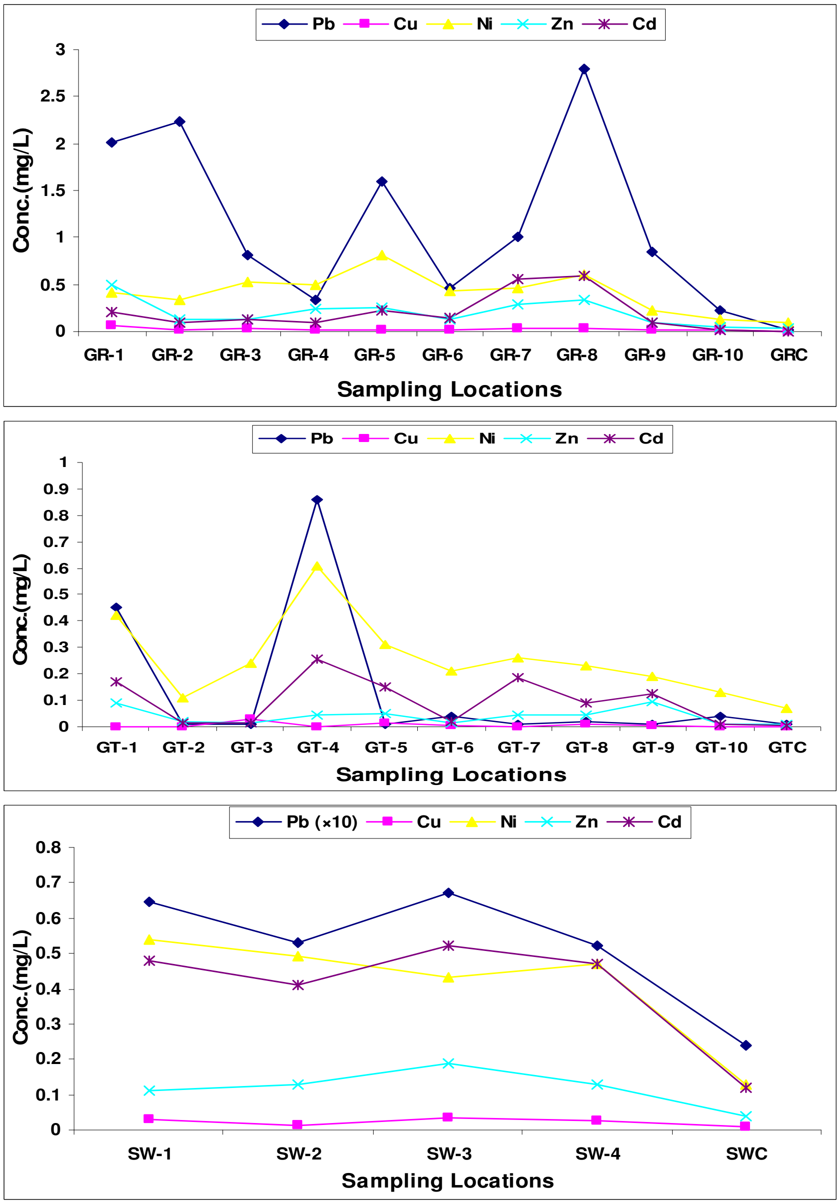

Figure 2. (A) Metal variation across sampling points of wells without rings; (B) Metal variation across sampling points of wells with rings; (C) Metal variation across sampling points of surface water.

and particularly in its soluble form. The pattern of distribution is almost similar for GR's and SW's with mean concentrations of 0.44 ± 0.19 and 0.41 ± 0.16 mg/L. All the samples exceeded the WHO and FEPA/FMENV maximum permissible limit of 0.02 and 0.05mg Cu /L respectively (WHO, 1993; FEPA/FMENV, 1991). Consequent upon the levels obtained in this study, the water is said to be contaminated. This may not go down well with the people because, even in lower concentrations, Ni can cause allergic reactions apart from being carcinogenic (McKenzie and Smythe, 1998). Comparatively, levels obtained are lower to the 2.0 – 9.3 and 0.00 – 2.70 mg Ni/L reported in other studies (Asaolu, 1998; Ololade, 2008).

Copper is an essential element. In this study, least concentrations of all the metals were recorded in Cu. The mean (S.D) concentrations across the various sources are 0.024 (0.019), 0.007 (0.088) and 0.022 (0.011) for GR's, GT's and SW's respectively. The concentrations as reported across the study are less than the WHO and FEPA/FMENV maximum permissi-

Table 3. Correlation between heavy metal contents (mg/L) in the studied area.

		Pb	Cu	Ni	Zn	Cd
GR samples (n = 10)	Cu	0.282	1.000	-0.011	0.714*	0.267
GT samples (n = 10)	Pb	1.000	-0.315	0.913**	0.237	0.683*
	Ni	0.913**	-0.080	1.000	0.336	0.829**
SW samples (n = 4)	Pb	1.000	0.849	0.887*	0.867	0.969**
	Ni	0.887*	0.577	1.000	0.683	0.917*
	Zn	0.867	0.796	0.683	1.000	0.886*

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed). Data in bold forms indicate significant correlation based on Spearman correlation analysis.

ble limit of 2.0 and 0.1 mg/L respectively. Hence, adverse effects due to Cu are not expected from domestic use of the water from all the sources. The level of Cu in this study is quite comparable to the 0.00 – 0.17 mg/L range obtained from a related study (Osibanjo and Adie, 2007) but fell far below the 0.6 – 14.9 , 3.10 – 34.03 and 72 - 298 mg/L concentration range of other authors (Kakulu,1985; Asaolu, 1998; Ololade, 2008).

Zinc is one of the essential elements required for proper functioning of the body system. The levels as reported in water from GR's and SW's are much higher than those in water from GT's. It is however interesting to note that none of all the water samples recorded Zn at a concentration above the 3.0 mg/L maximum permissible limit as given by appropriate authorities (WHO, 1993; FEPA/FMENV, 1991). Based on the guidelines, the water is free of any possible toxicity resulting from Zn metal or its compound. All the water can also be suitable for aquaculture, livestock watering and irrigation with guidelines of 0.003, < 0.1 and < 0.1 mg/L respectively (US EPA, 2004).

Cadmium occurs naturally in Zn, Pb, Cu and other ores which can serve as sources to ground and surface waters, especially when in contact with soft, acidic waters as observed in the present study. Major releases of cadmium are due to waste streams and leachate from landfills or refuse dumpsite especially the corrosion of some galvanized plumbing and water main pipes (National Primary Drinking water Regulations (NPDWRs), 2004). Comparatively, 100% samples of water from both GR's and SW's and about 60% of samples from GT's exceeded both the 0.003 mg/L (WHO,1993) and 0.01 mg/L (FEPA/FMENV, 1991) maximum permissible limit for Cd in water for domestic and other uses. The abnormally high values of Cd recorded at GR-5, GR-7 and GR-8 can be due to the closeness to the roadside and mainly through the activities of the mechanic workshops which surrounds these locations.

Details of statistical analyses based on Pearson correlation is presented in Table 3. Only copper and zinc were significantly correlated (r = 0.714) in water samples from GR's. For water from GT's, Pb concentrations were found to be insignificantly negatively correlated with Cu (- 0.3151). The same is also true between Cu and Ni (- 0.080), Zn (- 0.213) and Cd (- 0.285). However, Spearman's correlation ($P < 0.05$) gave significant correlations between Pb and Ni (0.533) and Cd (0.683). The same is true between Ni and Cd (0.829). Significant positive correlations were equally observed between Pb and Ni (0.887), Cd (0.969) and between Cd and Ni (0.917) and Zn (0.886) in samples from SW's. Consequent upon the levels recorded in this study, pollution resulting from Pb, Cd and Ni may become inevitable. Such health problems as kidney, liver, bone and blood damage may occur. The comparatively high values of Pb, Cd and Zn in surface water at the control sites (SWC) along with those from the sampling locations can be associated with the diffuse nature of Pb and run-off activities in Cd/Zn/Pb containing materials. This was further confirmed by the results from the underground water control sites, GRC and GTC (where run-off activities are minimal). Values obtained were very insignificant and in most cases non-detectable.

Conclusion

The level of metals and other physico-chemical parameters observed in this study have shown that the majority of the water utilized from the various natural sources examined is polluted. This was observed mainly to be due to the indiscriminate dumping of wastes into the environment. This is a major threat to human population, especially those within the area. Consequently, it is therefore recommended that effecttive disposal mechanism of household waste in Nigeria, and Ikare Akoko of Ondo state in particular, be introduced that would enhance sustainable development. In addition, a program of effective monitoring of water quality needs to be re-emphasized.

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