EVALUATION OF THE PHYSICOCHEMICAL PROPERTIES AND HEAVY METAL LEVEL OF WELL WATERS WITHIN THE VICINITY OF AUTO MECHANIC WORKSHOPS IN GWAGWALADA AREA COUNCIL, ABUJA, NIGERIA

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Clifford Baba Okpanachi[1]*, Iji Martins[2], Ismaila Ibrahim[1], Lukman Upahi[3]
[1]Department of Chemistry, Ahmadu Bello University, Zaria, Kaduna State, Nigeria
[2]Department of Chemistry, Abubakar Tafawa Balewa University, Bauchi State, Nigeria
[3]Department of Biology, Ahmadu Bello University, Zaria, Kaduna State, Nigeria
*Corresponding author: cliffordokpanachi@yahoo.com

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Abstract: Well water samples were collected from the vicinities of different auto mechanic workshops and a control site in Gwagwalada area council. The results of the physicochemical analysis which were determined by standard analytical techniques showed that pH values ranged from 5.2 – 6.8, Water temperature : 27.3 – 28.0ºC, Alkalinity : 22.8 – 38.7 mg/L, Turbidity : 3.67 – 16.13 NTU, Electrical conductivity (EC): 228.7 – 357.8 µS/cm, Total dissolved solids (TDS): 69.58 – 260.7 mg/L, Total hardness (TH): 51.8 – 126.3 mg/L, Sulphate (SO_4): 41.6 - 85.4 mg/L, Phosphate (PO_4): 5.11 – 8.26 mg/L, Nitrate:11.33 – 29.45 mg/L Chloride: 51.8 – 66.8 mg/L, dissolved oxygen (DO): 5.1- 7.2 mg/L, Chemical oxygen demand (COD): 12.17 – 24.82 mg/L. The mean heavy metal concentration in the well water samples which was determined by atomic absorption spectrophotometry showed that the results ranged from Cd: BDL – 0.38 mg/L, Cu: 2.08 – 6.52 mg/L, Ni: 0.06 – 0.32 mg/L, Pb: BDL – 0.11 mg/L, Zn: 6.01 – 14.15 mg/L. The results indicated that the water sources were contaminated and unfit for human consumption as they exceeded WHO recommended limits. Statistical analysis using Pearson's correlation coefficient indicated significant correlation of the heavy metals amongst themselves and notable physicochemical parameters suggesting anthropogenic origins. Wells which are used for drinking should not be dug near auto mechanic workshops. Also there should be comprehensive waste management plan for the inhabitants to follow on daily waste disposal, education on the dangers of drinking polluted water and effective water treatment before drinking.

Keywords: Automechanic workshops, heavy metals, physicochemical property, pollution, water

Introduction

Water is indispensable. It is not only essential for the survival of man but also for other living organisms. It is involved in every function of the human body and by all living things for cell metabolism, hence continuous existence of man on this planet will definitely depend on its availability (Pavendan *et al*., 2011). It is a vital resource on which human activities depend upon especially in the areas like agriculture, industry, transportation, domestic uses and recreation (Awomeso *et al*., 2010). In order to meet the rising water needs, evaluation of water quality is important for allocation to various uses thus making it imperative that thorough examination has to be conducted on it (Abbasi, 1999).

Heavy metal is a general term used to describe a group of metals and metalloids with an atomic density greater than 5.0 g/cm^3 (Duffus, 2002). These elements occur naturally in soils and rocks at various ranges of concentrations as well as in ground and surface water bodies and sediments (Hutton and Symon, 1986). Heavy metal pollution refers to cases where the quantities of heavy metals are higher than the maximum allowable concentrations, and this is potentially harmful to biological life at such locations (Gazso, 2001). Its presence in groundwater can pose a significant threat to human health and ecological systems. The chemical form of the metal contaminant influences its solubility, mobility, and toxicity in ground-water systems and depends on the source of the metal, the soil and ground-water chemistry at the site (Ogabiela *et al.*, 2011).

Human activities often result in water pollution making such water unfit for use. The activities at the mechanic workshop generate wide varieties of wastes which include petrol, grease, oils, suspended solids, organic solvents and so on, that find their way to the hydrological cycle thereby polluting or contaminating water resources (Obiefuna and Sheriff, 2011). High level of pollutants mainly organic matter in water cause an increase in biological oxygen demand (Kulkarni 1997), chemical oxygen demand, total dissolved solids, total suspended solids and fecal coli form, hereby making water unsuitable for drinking, irrigation or any other use (Hari 1994). The effect of uncontrolled disposal systems can render groundwater and surface waters unsafe for human, agricultural and recreational use, pose a threat to human life and is therefore against the principle of sustainable development (Abii and Nwabienvanne, 2011). This situation could be attributed to low level of awareness among the inhabitants, non enforcement of water laws and pollution control measures which apply to the water resources in the study area. Therefore, there is use of water from these sources ignorantly despite the cumulative health implication of such exercise.

The aim of the research is to assess the physicochemical parameters and heavy metal levels in well waters as a result of activities at auto mechanic workshops in Gwagwalada area council and to compare the results with existing standards for water quality evaluation.

Materials and Methods

Study area and sampling

Gwagwalada is one of the largest area councils in the F.C.T. It lies within latitude 8° 56' to 8° 29' N and longitude 7° 5' to 7° 31' E. It has an area of about 1069.589 square kilometers and falls within the Guinea savannah vegetation (Balogun, 2001). Water samples were collected from hand dug wells within the auto mechanic workshops across five districts namely; Dagiri (DG), Gwako (GK), Gwagwalada central (GC), Kutunku (KT) and Zuba (ZB). Control samples were also collected from wells about 1km away where no activities involving disposal of metal containing materials was involved. The water samples were collected with plastic containers, immersed below the water surface, filled to capacity, brought out of the water, properly sealed and labeled. The samples were immediately stored on ice in a dark cooler box and transported to the laboratory for analysis.

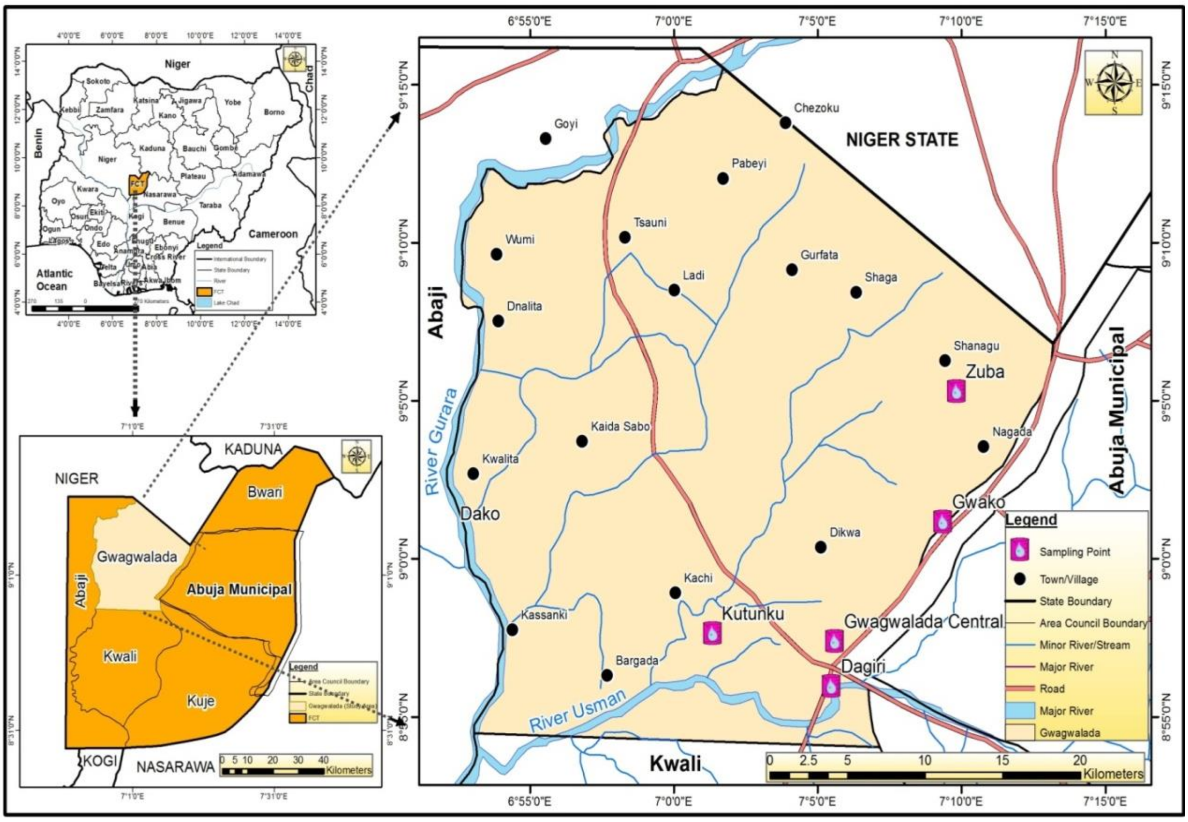

Fig 1: Map showing the five sampling sites

Physicochemical analysis

Water temperature was measured in-situ using mercury-in glass thermometer. The turbidity of the water was also measured in-situ by using a Turbidimeter. pH and conductivity were measured in the laboratory with a pH meter and conductivity meter, respectively. Total dissolved solids (TDS), Total hardness, Alkalinity, Dissolved oxygen (DO), Chemical oxygen demand (COD), Nitrate, Chloride and Phosphate were analysed using standard laboratory procedures as described by APHA (1998),

Heavy metal analysis

Concentrated HNO_3 (2.5 ml) was added to 50 ml of the sample and digested until a colorless solution was obtained. The digested sample was filtered to remove insoluble materials and the volume of the digested sample made to 50 ml with distilled water (Ademorati, 1996). The samples were analyzed for Cd, Cu, Ni, Pb and Zn using an Atomic Absorption Spectrophotometer. All assays were done in triplicates.

Results and Discussion

Physicochemical properties of the well water samples

The temperature of the sampled well waters ranged between 27.3 to 28.0°C with the control sample recording 28.2°C. Cool waters are generally more portable for drinking purposes, because high water temperature could enhance the growth of micro-organisms, hence taste, odour, colour, and corrosion problems may increase (Okoye and Okoye, 2008). The pH values obtained from waters at the study area ranged from 5.2 (Zuba) – 6.8 (Kutunku) (Table 1) which was slightly acidic while in the control sample, it was 7.5 indicating a neutral to slightly alkaline nature. The pH of water is very important in the determination of water quality since it affects other chemical reactions such as solubility and metal toxicity. With exceptions of samples from Dagiri and Zuba, the pH of the well water samples in this study were found to be at similar range with World Health Organization (WHO, 2008) limits of 6.0 – 8.5.

Electrical conductivity levels of the water samples in the study sites varied between 228.7 (Kutunku) and 357.8 µS/cm (Zuba). Conductivity levels were relatively low compared to WHO, 2008 guideline limit of 500 µS/cm. However, comparing this to that of the control sample which recorded a much lower level of 187.2 µS/cm, it is evident that, there is an influence from anthropogenic sources despite the low conductivity levels in the water sources. Turbidity levels of the water samples in the study site ranged between 3.67 to 16.13 NTU with water samples in Dagiri study area recording the highest values whilst the lowest value was recorded in Gwagwalada Central. The high turbidity values recorded at Dagiri which is a measure of undissolved materials could be as a result of sediment bearing runoff, suspended irons, and microorganisms amongst others from auto mechanic activities which could have caused significant amounts of algal blooms (Akoto and Adiyiah, 2007). The control sample was within WHO, 2008 acceptable limit of 5 NTU.

Total dissolved solids (TDS) values of the well water samples ranged from 69.58 – 260.70 mg/L which were below 500 mg/L (WHO, 2008) permissible limit for potable water. The presence of these total dissolved solids (TDS) in the water samples as observed in Table 1 indicated the presence of solid materials or solutes in water. Zuba study area had the highest TDS while water samples in Gwagwalada Central had the least values. The noticeably high values in Zuba could be due to differences in organic matter that remains as residue in the well water, also possibly due to exposure to air and environmental pollutants (Aremu *et al.*, 2011). The alkalinity values of all the sampled waters were below the stipulated limit of 100 mg/L by WHO (2008). They ranged from 22.8 to 38.7 mg/L in the studied samples and 39.1 mg/L in the control samples; this again confirmed the slightly acidic nature of water of the study area.

The sulphate content of studied water samples ranged from 41.6 mg/L (Gwagwalada central) to 85.4 mg/L (Zuba) and a value of 57.2 mg/L in the control sample. The values were low compared with the WHO permissible limits and therefore are incapable of causing bad smells. Sulphates are formed due to the decomposition of various sulphur containing substances present in water bodies. The sulphate ions (SO_4^{2-}) also occur naturally in most water supplies and hence could be a reason for its presence in significant amount in the control samples. The Chloride content of studied water samples ranged from 51.8 mg/L (Gwako) to 66.8 mg/L (Dagiri) and a value of 52.2 mg/L in the control sample. Chlorides are found in variable amount in groundwater, they are very stable components in water and its concentration is largely unaffected by most natural physicochemical and biochemical processes. Hence the value of its concentration in water is a useful measure in water sample.

The phosphate content of the water samples at the mechanic workshops ranged from 5.11 mg/L (Gwako) to 8.26 mg/L (Zuba). Significant variation was also observed between study samples and the control sample which recorded a much lower value of 5.06 mg/L. This could be due to the activities of battery servicing or higher organic matter contents as a result of petroleum hydrocarbon, an indication of contamination of the water within the study areas (Stephen *et al*., 2015). Phosphate is a generic term for the oxy-anions of phosphorous. Enrichment of water with organic phosphates results in an excessive growth of plants and other micro-organisms leading to eutrophication and increased biochemical oxygen demand. The nitrate content of the studied water samples varied between 11.33 (Kutunku) and 29.45 mg/L (Zuba). The values obtained were higher than that of WHO limits for drinking water. Nitrates indicate the presence of fully oxidized organic matter. The implication of this is that the well water analysed contain high level of oxidized organic matter which appears in the form of soluble anions such as nitrates.

Dissolved oxygen values ranged from 5.1 to 7.2 mg/L with the control sample having a value of 8.4 mg/L. The DO values for the studied samples were slightly below the WHO, 2008 permissible values of 7.5 for drinking water. This is an indicative of a slight pollution of the groundwater which might be attributed to the significant amount of organic materials discharged requiring high levels of oxygen for chemical oxidation, decomposition or break down by microbial organisms and seepage of heavy metals from soil at mechanic workshops (Chavan *et al*., 2005). The COD values observed were very high, showing a high level of contamination of the water samples. Since dissolved oxygen in natural waters depends on the physical, chemical and biochemical activities in the water body (APHA, 1998). The depletion of the oxygen load in the groundwater sampled could be linked to the high chemical activities likely to be going on in the water. One of such chemical activity as described by Okonkwo (2000) is chemical oxidation processes. (COD), like oxidation of iron to ferrous and ferric ions. Total hardness values ranged from 51.8 mg/L (Gwagwalada central) to 126.3 mg/L (Dagiri) with the control sample having a value of 42.1 mg/L. Based on the classifications by World Health Organization (WHO, 2008) International Standard for Drinking Water, the water samples analysed are moderately hard, with the water sample at the control site being soft.

Table 1: Physicochemical parameters of the water samples in the study area

Parameters	Dagiri	Gwagwalada Central	Gwako	Kutunku	Zuba	Control	WHO (2008)
pH	5.8	6.5	6.6	6.8	5.2	7.5	6.0 – 8.5
TEMP (^oC)	27.3	27.4	27.3	28.0	27.7	28.2	30.0
TUR (NTU)	16.13	3.67	4.06	8.18	10.03	3.19	5
TDS (mg/L)	242.03	91.00	87.07	69.58	260.70	50.11	500
Alkalinity (mg/L)	25.6	38.7	36.7	32.3	22.8	39.1	100
Phosphate (mg/L)	7.34	6.43	5.11	5.67	8.26	5.06	5
Nitrate (mg/L)	26.43	17.36	17.07	11.33	29.45	7.36	10
Sulphate (mg/L)	73.8	41.6	53.4	58.6	85.4	57.2	400
Chloride (mg/L)	66.8	55.5	51.8	64.1	65.3	52.2	250
Total Hardness (mg/L)	126.3	51.8	72.6	53.6	100.4	42.1	200
Dissolved Oxygen (mg/L)	5.1	7.2	5.9	6.4	5.3	8.4	7.5
COD (mg/L)	24.82	12.17	14.02	14.16	18.15	9.61	7.5
EC (μS/cm)	346.5	266.1	263.4	228.7	357.8	187.2	500

Cadmium concentration in water samples from the study site were in trace quantities and below the detection limit with exception of samples from Dagiri (0.32 mg/L) and Zuba (0.38 mg/L) which recorded high levels above WHO (2008) permissible limit of 0.003 mg/L. This might be as a result of effluents arising from the disposal of waste containing cadmium such as metal plating and coating operations, waste batteries and paints. Absence of cadmium in other sites might be due to sorption processes that might have occurred in solid (soil) surfaces (Kodom *et al*., 2009; Espeby and Gustafsson, 2001). Cd levels in control samples were also beyond detection limit (2).

Copper had relatively high values ranging from 2.08 mg/L (Kutunku) to 6.52 mg/L (Zuba) with the control sample recording 1.05 mg/L. The exceptionally high value in Zuba could be attributed to automobile wastes containing electrical and electronic parts, such as copper wires, electrodes and copper pipes and alloys from corroding vehicle scraps which have littered the vicinity for a long time, with the metals released from the corrosion gradually leaching through the soil into the well water (Nwachukwu *et al*., 2011). Copper concentration in most workshops well water samples were above standard limits (2.0 mg/L) set by WHO (2008).

Nickel concentration ranged from 0.06 (Gwako) to 0.32 mg/L (Gwagwalada Central) with the control sample recording 0.05 mg/L**.** Nickel concentration in the well water samples were generally above the WHO (2008) permissible limits of 0.02 mg/L thus implying high contamination of the metal in the water samples. This could be attributed to the disposal of spent automobile batteries from the nearby auto battery chargers and various paint wastes which would have leached through soil into the ground water. Ni causes skin damages and asthma symptoms in about 10 to 20% of the population that has direct contact with it (Lenntech, 2009).

Table 2: Mean concentration of heavy metals (mg/L) in waters of the study area

Location	Cd	Cu	Ni	Pb	Zn
Dagiri	0.32±1.82	5.55±0.73	0.09±0.31	0.08±0.31	12.86±0.49
Gwagwalada central	BDL	4.96±0.86	0.32± 0.00	0.03±0.89	8.35±0.24
Gwako	BDL	3.37 ±0.17	0.09±0.37	0.05±0.01	6.01±0.03
Kutunku	BDL	2.08±0.26	0.06±0.16	BDL	9.29±0.88
Zuba	0.38±0.23	6.52±0.14	0.08±0.44	0.11±0.58	14.15±0.93
Control	BDL	1.05± 0.77	0.05±0.88	BDL	3.11± 0.62
WHO (2008)	0.003	2.00	0.02	0.01	5.00

± 0.00 = Standard Error; BDL = Beyond detection limit

Lead had relatively high values ranging from BDL (Kutunku) to 0.11 mg/L (Zuba) with the control sample having values beyond the detection limit. Lead concentration in most of the study areas were generally above the standard limits (0.01 mg/L) set by WHO (2008). Source of lead in the water sources could be from the indiscriminate disposal of waste from lead-acid batteries, lead-based solder, metallic alloy, lead-based paints, used oil, waste incineration, scrap and junk auto parts (Nkansah *et al*, 2011). These parts may be coated with oil or grease, which may contain lead residues that create harmful storm water runoff endangering aquatic life, and public drinking water supplies. Also leachates from these wastes via water run-off are released directly into the well water.

The zinc content of the well water samples had values ranging from 6.01 (Gwako) – 14.15 mg/L (Zuba). These values were higher than the WHO (2008) limit of 5.00 mg/L in drinking water with the exception of the control sample. Zn has been found to have low toxicity to man, but, prolonged consumption of large doses can result in some health complications such as fatigue, dizziness, and neutropenia (Hess & Schmid, 2002). The presence of the high zinc content in the groundwater of the study sites could be attributed to the activities of the spray painter and also vehicle body paints which would have leached through soil into the ground water.

Correlation matrices

A correlation matrix was applied to see if some heavy metals and physicochemical parameters were interrelated with each other (Table 3). In general, parameters like EC, TDS and turbidity strongly correlated positively amongst themselves while DO and temperature had negative correlation with most parameters.

Table 3: Correlations matrix of the physicochemical parameters and the metals

	pH	TEMP	TUR	TDS	AKL	PHOS	NTR	SUL	CHL	TH	DO	COD	EC	Cd	Cu	Ni	Pb	Zn
pH	1																	
TEMP	-0.78**	1																
TUR	0.56	0.63*	1															
TDS	-0.43	-0.76**	0.83**	1														
AKL	0.87**	0.68*	0.50	-0.81**	1													
PHOS	-0.65*	-0.16	0.71**	0.78**	-0.43	1												
NTR	0.38	-0.22	0.33	0.63*	-0.37	0.62*	1											
SUL	-0.54	0.51	-0.12	0.15	0.65*	0.79**	0.60*	1										
CHL	0.46	-0.53	0.84**	0.72**	0.06	0.83**	0.82**	0.52	1									
TH	-0.72**	-0.34	-0.21	0.19	-0.57	0.86**	0.93**	0.78**	0.64*	1								
DO	-0.73**	0.92**	-0.87**	-0.84**	-0.18	-0.67*	0.71**	-0.31	0.55	-0.82**	1							
COD	0.75**	-0.16	0.85**	0.83**	0.44	0.81**	0.68*	0.64*	-0.81**	-0.63*	-0.83**	1						
EC	-0.29	-0.82**	0.91**	0.97**	0.92**	0.56	0.85**	0.62*	0.77**	0.97**	-0.61*	-0.56	1					
Cd	-0.31	0.43	-0.59	0.93**	0.37	0.68*	-0.64*	0.36	0.75**	0.64*	0.03	0.36	0.65*	1				
Cu	0.53	-0.41	-0.26	-0.77*	-0.52	0.52	0.02	0.44	0.64*	0.63*	-0.71**	-0.52	0.46	0.74**	1			
Ni	-0.61*	0.36	0.11	0.38	-0.14	0.89**	0.45	0.52	0.81**	0.54	-0.34	0.47	0.54	0.81**	0.57	1		
Pb	0.52	0.44	-0.23	-0.66*	0.53	0.61*	-0.61*	-0.45	-0.10	0.48	0.38	-0.06	0.43	0.61*	0.74**	0.72**	1	
Zn	-0.81**	-0.37	0.46	0.33	-0.28	0.45	0.56	0.41	-0.63*	0.72**	-0.59	-0.54	0.62*	0.76**	0.83**	0.84**	0.86**	1

*Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2- tailed)

Correlation between metals (inter-element correlation) were generally positive with strong correlations between Cu and Cd, Cd and Zn, Ni and Cd, Pb and Cu, Cu and Zn, Pb and Zn. these positive correlations indicate a possible common pollution source which could be as a result of anthropogenic activities from the Auto mechanic workshops (Hariprasad and Dayananda, 2013).

Conclusion

The results obtained from this study have shown that well waters sampled within the vicinity of auto mechanic workshops in Gwagwalada had heavy metals which exceeded the permissible limit of the world Health Organization (WHO, 2008). The heavy metals at the sampled waters were also higher in relative to the control sample; this could be attributed to the activities within these areas that generated waste, ranging from spent oil to metal wastes which contaminated the well waters with heavy metals. The results also showed that a notable amount of the physicochemical parameters determined exceeded the permissible limit of the world Health Organization (WHO, 2008) indicating pollution. The significant correlation of the heavy metals amongst themselves and notable physicochemical parameters suggest anthropogenic origins which further confirms the effect of auto mechanic activities.

Hence, it is recommended that wells which are used for drinking should not be dug near auto mechanic workshops, adequate measures should be taken immediately to ensure regular and adequate supply of treated water to the area; this will reduce the use of well water to activities other than for drinking purposes. Mechanic materials which are considered as scraps should be dumped far away from settlements to avoid the seeping of these metals to underground waters due to disintegration and finally there should be provision of regulatory guidance and recommended pollution prevention opportunities to help mechanics to handle their waste in cost-effective and environmentally sound ways.

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