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Original Research Article

Physicochemical Qualities of Groundwater near Solid Waste Disposal Site in Aba, Abia State, Nigeria

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Abstract

Groundwater aquifer from solid waste dumpsites is probable of discharging toxic pollutant to groundwater which is unsafe to human health and local ecosystem. This study was conducted to examine the physicochemical qualities of groundwater around solid waste dumpsite in Aba, Abia State during wet and dry seasons. The physicochemical analysis of the groundwater samples was determined in accordance with the standards of the American Public Health Association (APHA). The results obtained from the groundwater samples were compared with World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) permissible limit of those studied parameters in drinking water. The physicochemical values obtained from the groundwater around the dumpsite in both season shows that some of the tested parameters existed in values higher than both WHO and NSDWQ standards for drinking water quality. The results also showed that the concentrations of cadmium, aluminum, iron and zinc were within the WHO and NSDWQ standard, whereas, the concentrations of chromium, copper and lead exceeded the WHO and NSDWQ standards for drinking water quality in both studied seasons. Findings from this study suggest that dumpsite solid waste could impact negatively on some physicochemical qualities of groundwater sited around their vicinity. Therefore, the location of solid waste dumpsites around residential areas should be discouraged.

Keywords: Groundwater, solid waste dumpsite, water quality, pollutants, leachate.

INTRODUCTION

Ground water is considered as the most important natural resource necessary for the existence of life, especially for human consumption, agriculture, and industrial purposes (Kambe and Sayena, 2016). The quality of drinking water is a major environmental and sustainability concern currently. Groundwater is a major source of drinking water in rural and urban areas. Ground water accounts for over 90% of the world's readily available freshwater and is a major portion of water supply for domestic and industrial purpose (Omofunmi *et al*., 2020). The presence of micro-organisms and soluble salts has been identified as a major factor affecting quality of drinking water (Mokuolu *et al*., 2017).

Over the years, anthropogenic activities within the urban and industrial sectors have generated large amounts of solid wastes on a daily basis, which has affected groundwater quality especially in the developing counties, such as Nigeria. In Nigeria, open dumpsite and landfills have been the most widely used method for solid waste disposal. However, in the developing economies, open dumping has been the major unfriendly waste disposal approach to waste management, despite the numerous effects in the environment (Okunade *et al*., 2019). In open dump sites, waste is exposed to precipitation, which significantly produced toxic leachate. The toxic leachate which is rich in organic and inorganic constituents negatively affects the physiochemical composition of groundwater making it unsuitable for both human and industrial use (Kamble and Saxena, 2017). The amount of leachate generated from open dumpsites depends on the moisture content of the waste and the amount of precipitation that passes through the dump sites (Aramide, 2023).

Leachate is generated from waste when water penetrate through the waste and causes solubulization of organic and inorganic constituents of the waste through oxidation, decomposition of organic matter and corrosion of metallic components (Okunade *et al*., 2019). Leachate constituents rely on various factors, such as, composition and nature of waste, waste compaction, particle size, soil moisture, type of microorganisms, temperature of the waste, climate, age of the dumpsite and hydrogeology of the location (Aramide, 2023). However, groundwater is expected to be less polluted when compared with surface water due to its natural filtration properties. Recent studies have shown that water from most hand dug wells and ground water are contaminated by leachates from sewages, municipal waste dumpsites and hydrocarbons located in their vicinities (Idise and Igborgbor, 2017). The generated leachate contaminates the surface soil and water around the environment, and move through the dumpsite to the bottom and beneath the soil until it gets to the ground water zone by pull of gravity (Igboama *et al*., 2022). The leachate produced from the waste can significantly affect the soil surface and groundwater resources and affect the portability of the underground water. The physicochemical and microbiological qualities of groundwater indicate the suitability of the water for human and animal consumption, agricultural, industrial and other purposes (Igboama *et al*., 2022). Consequently, proper maintenance, evaluation and monitoring of dumpsites especially within environments with facilities for water exploitation are very important in reducing leachate contamination and ensuring the quality of groundwater.

The potential contaminations of groundwater from dumpsite leachate in Aba are major concerns over quality and safety of the water supply to the population. Studies have shown that approximately 47.3% of total solid waste generated in Aba is organic and biodegradable, compared to 4.69-9.90% or recyclable waste (Okeke *et al.*, 2023). The groundwater is exploited as borehole water and majority of the people in Aba depend on these boreholes for their portable water needs due to lack of public water supply infrastructure. Hence, the health of the public residing in the vicinity of the dumpsite in Aba municipal is exposed to potential public health threats. In this study, groundwater around Aba dumpsite was investigated to determine the effect of leachate from the dumpsite on the physicochemical quality and microbial loads of groundwater around the selected dumpsite located at Ogbo Hill, Aba, Abia State, Nigeria.

MATERIALS AND METHODS

Description of the Study Area and Sampling Location

The study area was Umu Ohia dumpsite at Ogbo hill, Aba, Abia State, Nigeria. It is situated within the South-Eastern Nigeria (Figure 1) and lies on longitude $5^0$13'67'37.6" N and latitude $7^0$37'38' 70.4" E. The dumpsite is located close to residential houses and river as shown in Figure 2. The study period covered two seasons, wet and dry. The wet season starts in March and lasts till end of November with its peak period in July. The dry season runs from November till early March with its peak between December and February.

Figure 1: The General Positioning System Map of Aba Dumpsite Location in Abia State, Nigeria

Figure 2: Aba Dumpsite in Aba, Abia State, Nigeria

Water Sample Collection

This study was designed to cut across dry and wet season in Nigeria. Ground water samples were collected from boreholes located in two different residential buildings within the dumpsite (Figure 2) area and labeled Aba groundwater GW1, GW2 and control, respectively. The groundwater sample collected in July represents the wet season in the study area while samples taken in January represented the dry season situation of water quality. The groundwater samples were taken within 100 meters proximity of the dumpsite in 1 litre high density polyethylene bottles, and preserved at 4^0C with ice pack prior to analysis. A control point was purposely taken 5 km away from the dumpsite.

Determination of Physiochemical Parameters

The physical parameters were analyzed immediately after collection. Temperature was determined using mercury in glass thermometer, pH was determined using the portable digital pH meter (Jenway), and conductivity meter (Jenway 4510) instrument were used to determine electrical conductivity and total dissolved solids (TDS), respectively. The groundwater samples were analyzed for the following physicochemical parameters and heavy metals; alkalinity turbidity, total suspended solid, chloride (Cl^-), nitrate (NO_3^{2-}), sulphide (SO_3^{2-}), acidity, dissolve oxygen (DO), phosphate (PO_4^{2-}), chemical oxygen demand (COD), bicarbonate (CO_3^{2--}), iron (Fe), lead (Pb), chromium (Cr), zinc (Zn), Aluminum (Al), cadmium (Cd), nickel (Ni) and copper (Cu). The analysis of these water quality parameters were conducted in accordance to standard analytical methods (APHA, 2005). The results obtained on the various physicochemical properties were compared with those of the WHO, 2007 and NSDWQ, 2007, respectively.

RESULTS AND DISCUSSION

Physicochemical Characteristics of Groundwater Around Dumpsite

The physicochemical characteristics of collected groundwater around the dumpsite during wet and dry seasons are presented in Table 1. Descriptive analysis of collected groundwater parameters in wet and dry seasons in Aba, Abia State are presented in tables 2 and 3, respectively. The groundwater temperature from the two study locations were both 28.0 ℃ and was 27.0 ℃ at the control location during the wet season while location GW1, GW2 and control were 29.0 ℃, 28.5℃ and 28℃, respectively during the dry season. The slight difference in temperature observed in dry and wet seasons is as a result of high evaporation during dry season. The temperature of the study area falls within appropriate range (22-30^{0}C). Studies have shown that temperature of water influences biological activities and also causes chemical reactions. High temperature increases mineral dissolution in rocks/soils (Ugbaja *et al.*, 2021).

The pH of the groundwater samples were acidic, with pH ranging from 4.5-5.5 and 4.1-5.0 during dry and wet seasons, respectively. The pH results indicate that all the ground water samples fall below the WHO and NSDWQ standards. The pH of water body is a very important parameter in determining water quality since it affects solubility and toxicity of metals in the aquatic system, which may be detrimental to human health (Okunade *et al*., 2019). The pH of the water samples shows that the groundwater needs to be treated before use. Groundwater in locations within Aba has been reported to have acidic pH (Okeke *et al*., 2023).

The electrical conductivity of the study area falls within 100-673 µS/CM for wet season while that of dry season was 107-112 µ S/CM. The electrical conductivity values of the groundwater samples were within the permissible levels of WHO and NSDWQ standards within the studied seasons. The high electrical conductivity observed during the wet season could be attributed to low evaporation and higher water-rock interaction (Ugbaja *et al.*, 2021).

The TDS values of groundwater ranged from 33 to 190mg/l and 45-174mg/l during wet and dry season showing that all the samples where within the permissible levels of 500 mg/l and 1000mg/l recommended by WHO and NSDWQ, respectively. The obtained lower TDS results revealed that the ground water in the studied area can be classified as fresh, and desirable for drinking water.

Turbidity is a measure of water clarity. The turbidity range units of control sample and ground water samples close to open dumpsite were within the limits (4.0 to 4.90) during wet season. The turbidity of control sample (2.0) was within the WHO permissible limit of WHO while the values from groundwater collected from closed dumpsite has high values at the two locations during the dry season.

The total suspended solid (TSS) values 1.300 to 1.970mg/l and 0.780 to 0.793 during wet and dry season were within WHO limits for drinking water. The high value of TSS observed during wet season might be because of infiltration of contaminated surface water or leaching from contaminated sites which is expected during wet season compared to dry season. The low levels of TSS shows that the groundwater samples can tolerate productivity of aquatic animals (Yakubu and Omar, 2019).

Alkalinity value is attributed to the age of the dumpsite and is correlated with pH (Yakubu and Omar, 2019). The alkalinity values were all within the permissible values of WHO and NSDWQ in both studied seasons.

The total acidity within the study area were in the range of 30-44mg/l and 50 to 62.50mg/l during wet and dry season, respectively. The permissible limit for total acidity in drinking water has not been specified by WHO.Studies however show that high acidity in water bodies can harm aquatic life and cause leaching of metals.

The range of chloride deposit in the study area is within 102.0 to 109.0mg/l and 40.0 to 64.0mg/l for wet and dry season, respectively. The chloride concentration in the groundwater was below WHO standard of 250mg/l for the two seasons studied. The chloride concentration of the groundwater during wet season is higher than the permissible standard while the chloride concentration during dry season is within the permissible standard of 100mg/l stated by NSDWQ. The higher chloride values observed during the wet season may be attributed to high rate of mineral leaching and dissolution.

Researchers have reported that high concentration of Nitrate in drinking water is harmful to human health. Nitrate, being a strong oxidizing agent can react with secondary amines present in human body to form nitrosamines. The exposure of humans to nitrate causes methemoglobinemia. The nitrate concentration in the groundwater in both seasons were lower than the WHO / NSDWQ permissible limit for drinking water. The low nitrate content obtained in the groundwater samples in both seasons shows that the groundwater does not pose much danger to human health subject to other parameters.

Other ions investigated in the groundwater samples were sulphide, sulphate, phosphate and bicarbonate and their results are presented in Table 1. It was observed that the sulphide, sulphate, phosphate and bicarbonate contents were within the WHO / NSDWQ regulatory limits in both wet and dry seasons.

Dissolved Oxygen (DO) is measured as amount of oxygen molecules dissolved in water. The presence of dissolved oxygen in water is essential for the survival of most aquatic plants and animal. High concentration of DO is a good indicator of water quality (Yakubu and Umar, 2019). The findings in this study show that all the water samples tested had values above the 5 mg/l WHO and 14 mg/l NSDWQ threshold, respectively. Biological Oxygen Demand (BOD) shows the amount of dissolved oxygen required by aerobic biological organisms in water to break down organic material present in water sample at particular temperature and specific time, whereas Chemical Oxygen Demand (COD) is the measure of the amount of oxygen needed for complete oxidation of carbon (IV) oxide and organic matter present in water. COD and BOD are vital water quality parameters that indicate the extent of organic pollution in water (Yakubu and Omar, 2019). The low level of COD values in both seasons suggest that the dumpsite did not alter the WHO permissible limit of COD. The BOD values were found to be higher than who recommended standard which may be an indication of pollution with the groundwater.

Metal Parameters around the Dumpsite

Metals are known to have beneficial or harmful effects to human body and animals. Heavy metal exerts toxic effects on human beings, aquatic life and the environment. Among the cations investigated, the concentrations of cadmium, aluminum, iron and zinc were within the permissible limit in both seasons studied. These indicate that these metals might not have accumulated substantially to levels that could be detrimental to human beings and aquatic animals. In contrast, the concentration of lead, chromium, copper exceeded the permissible limit in the groundwater for both seasons which may be of toxicological concerns to the environment.

Table 1: Physicochemical properties of groundwater obtained during dry and wet season in Aba, Abia State

Physicochemical Properties	Wet Season			Dry Season			WHO	NSDWQ
	Aba Control	GW 1	GW 2	Aba Control	GW 1	GW 2		
Temperature (°C)	27.00	28.00	28.00	28.00	29.00	28.50	22-30	Ambient
pH	4.10	4.700	5.000	4.500	5.00	5.50	6.5-8.5	6.5-8.5
Conductivity (µS/cm)	673.00	100.00	143.00	112.00	107.0	110.0	1000	500
Total Dissolved Solid (mg/l)	190.00	16.000	33.000	174.000	48.00	45.00	500	1000
Alkalinity (mg/l)	5.000	2.500	2.800	5.000	7.500	7.00	500	NS
Chloride (mg/l)	109.000	102.00	105.000	40.000	64.00	60.00	250	100
Nitrate (mg/l)	5.52	8.36	6.25	8.44	5.94	6.851	50	10
Sulphide (mg/l)	0.04	0.04	0.04	0.276	0.29	0.28		
Sulphate (mg/l)	70.339	67.79	68.38	96.928	97.22	98.79	250	100
Acidity (mg/l)	30.000	40.00	44.00	62.50	50.00	55.00		NS
Biological Oxygen Demand (mg/l)	7.360	7.340	7.300	8.90	5.200	6.200	10	NS
Turbidity (NTU)	4.90	4.00	4.400	2.00	6.40	6.90	5	5
Phosphate (mg/l)	6.01	7.91	7.82	7.869	8.58	8.98	NA	100
Total Suspended Solid (mg/l)	1.97	1.30	1.52	0.78	0.79	0.79	3	0.1
Chemical Oxygen Demand (mg/l)	288.00	288.00	287.00	40.00	24.00	32.00	10	NS
Bicarbonate (mg/l)	5.00	5.50	5.00	15.00	20.00	18.00	NA	
Aluminium (mg/l)	ND	ND	ND	0.002	0.015	0.011	0.2	0.5
Cadmium (mg/l)	0.025	0.027	0.025	0.022	0.009	0.012	0.003	NS
Chromium (mg/l)	0.034	0.022	0.020	0.067	0.080	0.062	0.05	0.004
Copper (mg/l)	0.058	0.013	0.014	0.045	0.031	0.035	2.0	1.0
Iron (mg/l)	ND	ND	ND	ND	0.250	0.216	0.3	0.3
Lead (mg/l)	0.060	0.115	0.107	0.006	0.064	0.030	0.05	0.004
Nickel (mg/l)	ND	ND	ND	0.062	0.102	0.097	NS	0.001
Zinc (mg/l)	0.036	0.017	0.015	0.182	0.187	0.197	3.0	5.0

WHO: World Health Organization
NSDWQ: Nigerian Standard for Drinking Water Quality
NS: Not Stated.

Table 2: Descriptive Statistics of Physiochemical Properties for Aba During Wet Season

Physicochemical Properties	MEAN	SD	MEAN-SD	MEAN+SD	SEM
Temperature (°C)	27.667	0.577	27.089	28.244	0.192
pH	4.600	0.458	4.142	5.058	0.153
Conductivity (µS/cm)	305.333	319.134	-13.800	624.467	106.378
TDS (mg/l)	79.667	95.929	-16.262	175.595	31.976
Alkalinity (mg/l)	3.433	1.365	2.068	4.798	0.455
Chloride (mg/l)	105.333	3.512	101.821	108.845	1.171
Nitrate (mg/l)	6.710	1.475	5.235	8.185	0.492
Sulphide (mg/l)	0.041	0.002	0.040	0.043	0.001
Sulphate (mg/l)	68.839	1.332	67.507	70.170	0.444
Acidity (mg/l)	38.000	7.211	30.789	45.211	2.404
BOD (mg/l)	7.333	0.031	7.303	7.364	0.010
Turbidity (NTU)	4.433	0.451	3.982	4.884	0.150
Phosphate (mg/l)	7.246	1.074	6.172	8.321	0.358
TSS (mg/l)	1.597	0.342	1.255	1.938	0.114
COD (mg/l)	287.667	0.577	287.089	288.244	0.192
Bicarbonate (mg/l)	5.167	0.289	4.878	5.455	0.096
Cadmium (mg/l)	0.026	0.001	0.025	0.027	0.000
Lead (mg/l)	0.094	0.030	0.064	0.124	0.010
Copper (mg/l)	0.028	0.025	0.003	0.054	0.008
Chromium (mg/l)	0.025	0.008	0.018	0.033	0.003
Zinc (mg/l)	0.023	0.012	0.011	0.034	0.004
Nickel (mg/l)	0.000	0.000	0.000	0.000	0.000
Aluminum (mg/l)	0.000	0.000	0.000	0.000	0.000
Iron (mg/l)	0.000	0.000	0.000	0.000	0.000

Table 3: Descriptive Statistics of Physiochemical Properties for Aba during Dry Season

Physicochemical Properties	MEAN	SD	MEAN-SD	MEAN+SD	SEM
Temperature (°C)	28.5000	28.000	56.500	0.2887	0.5000
pH	5.000	4.500	9.500	0.2887	0.5000
Conductivity (µS/cm)	2.5166	107.150	216.817	1.4530	2.5166
TDS (mg/l)	73.6274	15.373	104.373	42.5088	73.6274
Alkalinity (mg/l)	1.3229	5.177	11.677	0.7638	1.3229
Chloride (mg/l)	12.8582	41.808	96.475	7.4237	12.8582
Nitrate (mg/l)	1.2648	5.809	12.883	0.7302	1.2648
Sulphide (mg/l)	0.0050	0.276	0.557	0.0029	0.0050
Sulphate (mg/l)	0.9986	96.646	194.290	0.5765	0.9986
Acidity (mg/l)	6.2915	49.542	105.375	3.6324	6.2915
BOD (mg/l)	1.9140	4.853	11.619	1.1050	1.9140
Turbidity (NTU)	2.6963	2.404	7.504	1.5567	2.6963
Phosphate (mg/l)	0.5604	7.914	16.388	0.3235	0.5604
TSS (mg/l)	0.0066	0.780	1.567	0.0038	0.0066
COD (mg/l)	8.0000	24.000	56.000	4.6188	8.0000
Bicarbonate (mg/l)	2.5166	15.150	32.817	1.4530	2.5166
Cadmium (mg/l)	0.0068	0.008	0.022	0.0039	0.0068
Lead (mg/l)	0.0294	0.004	0.037	0.0170	0.0294
Copper (mg/l)	0.0072	0.030	0.067	0.0042	0.0072
Chromium (mg/l)	0.0093	0.060	0.130	0.0054	0.0093
Zinc (mg/l)	0.0076	0.181	0.370	0.0044	0.0076
Nickel (mg/l)	0.0216	0.065	0.152	0.0125	0.0216
Aluminum (mg/l)	0.0067	0.003	0.012	0.0038	0.0067
Iron (mg/l)	0.1353	0.020	0.175	0.0781	0.1353

Table 4: Correlation coefficient between the physicochemical parameters for Aba during wet season

	Temperature	**pH**	**Conductivity**	**TDS**	**Alkalinity**	**Chloride**	**Nitrate**	**Sulphide**	**Sulphate**	**Acidity**	**BOD**	**Turbidity**	**Phosphate**	**TSS**	**COD**	**Bicarbonate**	**Cadmium**	**Lead**	**Copper**	**Chromium**	**Zinc**	**Nickel**	**Aluminum**	**Iron**
Temperature	1																							
pH	-0.693	1																						
Conductivity	0.715	0.01	1																					
TDS	0.42	-0.95	-0.333	1																				
Alkalinity	0.5	0.28	0.963	-0.576	1																			
Chloride	-0.834	0.98	-0.21	-0.852	0.062	1																		
Nitrate	0.43	-0.95	-0.323	1	-0.567	-0.857	1																	

Sulphide	-0.064	-0.68	-0.743	0.879	-0.896	-0.498	0.873	1																
Sulphate	-0.986	0.81	-0.587	-0.567	-0.347	0.915	-0.576	-0.105	1															
Acidity	0.866	-0.96	0.27	0.818	0	-0.998	0.824	0.444	-0.938	1														
BOD	0.953	-0.88	0.47	0.676	0.214	-0.962	0.684	0.242	-0.99	0.977	1													
Turbidity	-0.881	0.95	-0.299	-0.8	-0.03	0.996	-0.806	-0.416	0.948	-1	-0.983	1												
Phosphate	0.113	0.64	0.775	-0.854	0.917	0.455	-0.848	-0.999	0.056	-0.399	-0.194	0.371	1											
TSS	-0.094	-0.65	-0.763	0.864	-0.909	-0.471	0.858	1	-0.075	0.416	0.212	-0.388	-1	1										
COD	0.5	0.28	0.963	-0.576	1	0.062	-0.567	-0.896	-0.347	0	0.214	-0.03	0.917	-0.909	1									
Bicarbonate	0	-0.72	-0.699	0.907	-0.866	-0.553	0.903	0.998	-0.169	0.5	0.303	-0.473	-0.994	0.996	-0.866	1								
Cadmium	0.31	0.47	0.886	-0.732	0.978	0.267	-0.725	-0.969	-0.145	-0.207	0.007	0.177	0.98	-0.976	0.978	-0.951	1							
Lead	0.037	0.69	0.725	-0.891	0.884	0.521	-0.886	-1	0.132	-0.467	-0.268	0.44	0.997	-0.998	0.884	-0.999	0.962	1						
Copper	0.355	-0.92	-0.4	0.997	-0.632	-0.812	0.997	0.91	-0.507	0.775	0.622	-0.755	-0.889	0.897	-0.632	0.935	-0.779	-0.921	1					
Chromium	-1	0.69	-0.715	-0.42	-0.5	0.834	-0.43	0.064	0.986	-0.866	-0.953	0.881	-0.113	0.094	-0.5	0	-0.31	-0.037	-0.355	1				
Zinc	0.058	-0.76	-0.656	0.93	-0.836	-0.6	0.926	0.993	-0.225	0.549	0.358	-0.523	-0.985	0.988	-0.836	0.998	-0.931	-0.996	0.954	-0.058	1			
Nickel	0.5	-0.97	-0.248	0.996	-0.5	-0.895	0.997	0.832	-0.639	0.866	0.739	-0.85	-0.804	0.815	-0.5	0.866	-0.668	-0.847	0.987	-0.5	0.893	1		
Aluminum	0.5	-0.97	-0.248	0.996	-0.5	-0.895	0.997	0.832	-0.639	0.866	0.739	-0.85	-0.804	0.815	-0.5	0.866	-0.668	-0.847	0.987	-0.5	0.893	1	1	
Iron	0.225	0.55	0.842	-0.79	0.956	0.351	-0.783	-0.987	-0.058	-0.292	-0.081	0.263	0.994	-0.991	0.956	-0.974	0.996	0.982	-0.831	-0.225	-0.96	-0.731	-0.731	1

Table 5: Correlation coefficient between the physicochemical parameters for Aba during dry season

	Temperature	pH	Conductivity	TDS	Alkalinity	Chloride	Nitrate	Sulphide	Sulphate	Acidity	BOD	Turbidity	Phosphate	TSS	COD	Bicarbonate	Cadmium	Lead	Copper	Chromium	Zinc	Nickel	Aluminum	Iron
Temperature	1																							
pH	0.5	1																						
Conductivity	-0.993	-0.397	1																					
TDS	-0.856	-0.876	0.791	1																				
Alkalinity	0.945	0.756	-0.901	-0.978	1																			
Chloride	0.933	0.778	-0.886	-0.984	0.999	1																		
Nitrate	-0.988	-0.626	0.964	0.925	-0.984	-0.977	1																	
Sulphide	1	0.5	-0.993	-0.856	0.945	0.933	-0.988	1																
Sulphate	0.146	0.93	-0.032	-0.637	0.462	0.492	-0.295	0.146	1															
Acidity	-0.993	-0.596	0.974	0.909	-0.976	-0.968	0.999	-0.993	-0.259	1														
BOD	-0.967	-0.705	0.931	0.96	-0.997	-0.994	0.994	-0.967	-0.395	0.99	1													
Turbidity	0.816	0.909	-0.744	-0.997	0.96	0.969	-0.895	0.816	0.691	-0.877	-0.937	1												
Phosphate	0.633	0.987	-0.541	-0.943	0.852	0.869	-0.744	0.633	0.858	-0.718	-0.811	0.964	1											
TSS	0.991	0.61	-0.97	-0.917	0.98	0.973	-1	0.991	0.276	-1	-0.992	0.885	0.73	1										
COD	-1	-0.5	0.993	0.856	-0.945	-0.933	0.988	-1	-0.146	0.993	0.967	-0.816	-0.633	-0.991	1									
Bicarbonate	0.993	0.596	-0.974	-0.909	0.976	0.968	-0.999	0.993	0.259	-1	-0.99	0.877	0.718	1	-0.993	1								

Cadmium	-0.955	-0.735	0.915	0.971	-0.999	-0.998	0.989	-0.955	-0.433	0.983	0.999	-0.951	-0.835	-0.986	0.955	-0.983	1							
Lead	0.995	0.413	-1	-0.801	0.909	0.894	-0.969	0.995	0.049	-0.978	-0.937	0.756	0.555	0.974	-0.995	0.978	-0.922	1						
Copper	-0.967	-0.704	0.931	0.959	-0.997	-0.994	0.994	-0.967	-0.394	0.99	1	-0.936	-0.81	-0.992	0.967	-0.99	0.999	-0.937	1					
Chromium	0.7	-0.269	-0.777	-0.229	0.427	0.396	-0.582	0.7	-0.605	-0.613	-0.493	0.158	-0.11	0.599	-0.7	0.613	-0.456	0.766	-0.494	1				
Zinc	0.327	0.982	-0.217	-0.769	0.619	0.645	-0.468	0.327	0.983	-0.434	-0.559	0.813	0.938	0.449	-0.327	0.434	-0.593	0.234	-0.558	-0.446	1			
Nickel	0.918	0.802	-0.866	-0.991	0.997	0.999	-0.968	0.918	0.526	-0.957	-0.989	0.978	0.888	0.962	-0.918	0.957	-0.994	0.875	-0.989	0.359	0.675	1		
Aluminum	0.976	0.676	-0.945	-0.948	0.993	0.989	-0.998	0.976	0.357	-0.995	-0.999	0.922	0.786	0.996	-0.976	0.995	-0.997	0.951	-0.999	0.528	0.524	0.982	1	
Iron	0.922	0.796	-0.871	-0.989	0.998	1	-0.97	0.922	0.518	-0.96	-0.99	0.976	0.884	0.965	-0.922	0.96	-0.995	0.88	-0.99	0.368	0.668	1	0.984	1

Correlation Analysis

The result of the correlation analysis of the investigated dumpsite groundwater parameters are tabulated in Table 4 and 5 respectively. The correlation of groundwater parameters displayed 276 correlation results. Relationship of two parameters were examined, 94 parameters were found to have positive correlations, 116 shows negative correlations while 66 shows zero correlation during wet season. A very strong positive correlation was observed in Aba sample to exist between Alkalnity and conductivity (0.999), alkalinity and TDS (1.00), TDS and conductivity (1.00), chloride and conductivity (0.931), TDS (0.938), alkalinity (0.946), sulphate and conductivity (0.988), TDS (0.991), alkalinity (.0994), chloride (0.976), strong positive correlation also existed between Acidity and temperature (0.961), phosphate and temperature, pH, acidity, respectively. Nickel, Aluminum and iron show zero correlation with other physicochemical parameters. Strong correlations were observed in 67 correlation results during dry season. Cadmium, nickel, aluminum and iron contributed majority of the good positive correlation of above (r = 0.900) between the other parameters studied from Aba groundwater sample.

Principal Component Analysis (PCA) of Groundwater in wet and dry season in Aba.

Principal component analysis serves as a very important tool for giving useful information in the evaluation and interpretation of water quality. Table 6 and 7 shows the PCA for groundwater from Aba during wet and dry season. The principal component analysis of physicochemical parameters, size percentage proportion and cumulative variance on the 2 principal components are shown in Table 8 and 9; and Figure 1 and 2. The ordination of 16 physicochemical parameters and 5 heavy metals extracted two principal components (Figure 1 and 2) in ground water from the Aba studied locations in both seasons. The components of wet season were as follows.

Component 1: This component described the physicochemical and metal component of groundwater sample during wet season. The low loading of physicochemical parameters heavy metals investigated at first component with Eigen values of 13.189 explained up to 62. 80 % of variation in the data set. The first component provides important information required for explaining most of the variations in the data set of physicochemical and heavy metal properties of Aba groundwater than other component. The presence of heavy metal loadings in the water showed that the parameters are from natural sources.

Component 2: This component showed that the physicochemical parameters and heavy metal presence were moderate with a very weak loading. The second component showed 7.811 Eigen value with 37.20 % data set.

The principal component analysis of physicochemical properties and heavy metals in Aba sample during dry season showed two components system.

Component 1: This component accounts for about 83.70 % of the total variation in the data sets with Eigen value of 20.098.

Component 2: This component has Eigen value of 3.902 and 16.30 % of variation in the data set. The principal component analysis shows that the water quality is not affected by the waste dump activities in the study area.

Table 6: The physical component matrix of ordination of physicochemical and metal from Aba during wet season

	Component	
Variable	**1**	**2**
Temperature	0.275	-0.005
pH	0.261	0.113
Conductivity	-0.274	0.029
TDS	-0.274	0.037
Alkalinity	-0.273	0.044
Chloride	-0.247	0.157
Nitrate	0.189	-0.26
Sulphide	0.048	-0.352
Sulphate	-0.268	0.083
Acidity	0.266	0.095
BOD	-0.211	-0.231
Turbidity	-0.245	0.163
Phosphate	0.275	-0.021
TSS	-0.259	0.12
COD	-0.141	-0.307
Bicarbonate	0.134	-0.312
Cadmium	0.134	-0.312
Lead	-0.108	-0.329
Copper	0.139	0.309
Chromium	0.171	0.281
Zinc	0.161	0.29

Table 7: The physical component matrix of ordination of physicochemical and metal from Aba during dry season

	Component	
Variable	**1**	**2**
Temperature	0.214	-0.145
pH	0.162	0.347
Conductivity	-0.205	0.2
TDS	-0.216	-0.127
Alkalinity	0.223	0.022
Chloride	0.222	0.039
Nitrate	-0.221	0.069
Sulphide	0.214	-0.145
Sulphate	0.094	0.459
Acidity	-0.22	0.088
BOD	-0.223	0.016
Turbidity	0.211	0.162
Phosphate	0.185	0.283
TSS	0.22	-0.08
COD	-0.214	0.145
Bicarbonate	0.22	-0.088
Cadmium	-0.223	-0.005
Lead	0.206	-0.192
Copper	-0.223	0.016
Chromium	0.104	-0.448
Zinc	0.13	0.411
Nickel	0.222	0.059
Aluminium	0.222	-0.036
iron	0.222	0.054

Table 8: The size, percentage total variation and cumulative percentages of co-relation matrix of the first two components in the original data set of scree plots composition of groundwater from Aba during wet season

Components	Initial eigen value		
	Total	% Proportion	% Cumulative
1	13.189	62.80	62.80
2	7.811	37.20	100.00

Table 9: The size, percentage total variation and cumulative percentages of co-relation matrix of the first two components in the original data set of scree plots composition of groundwater from Aba during dry season

Components	Initial eigen value		
	Total	% Proportion	% Cumulative
1	20.098	83.70	83.70
2	3.902	16.30	100.00

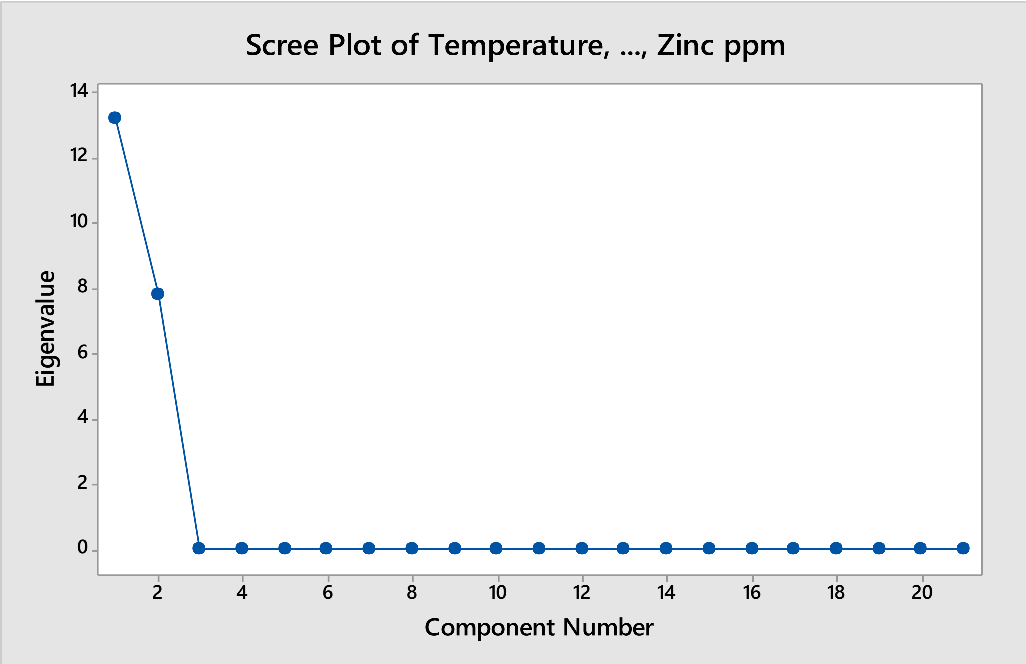

Figure 1: Ordination graph showing principal components of groundwater from Aba during wet season

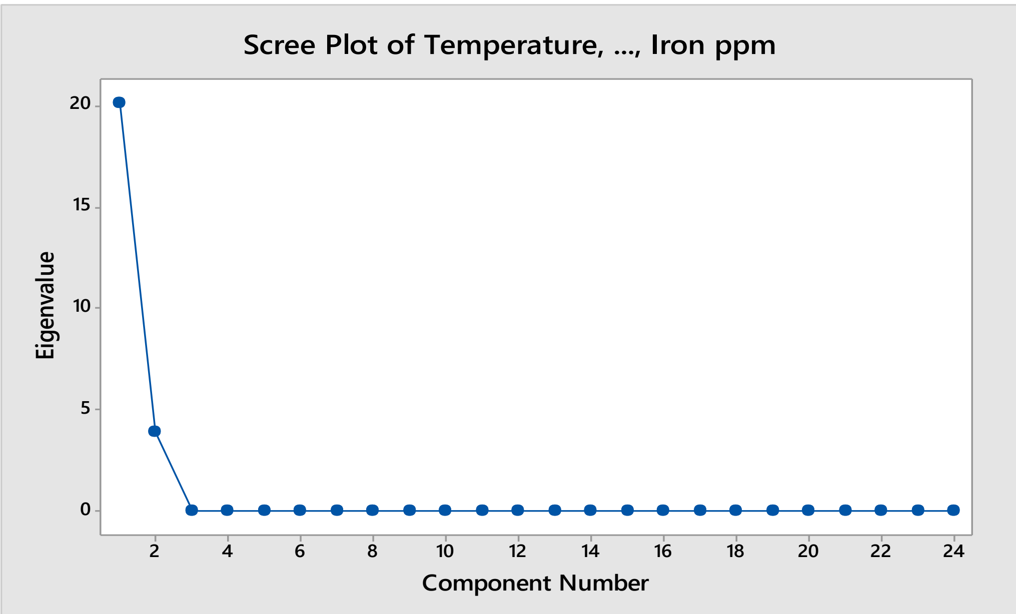

Figure 2: Ordination graph showing principal components of groundwater from Aba during dry season

CONCLUSION

The present study was carried out to examine the impact of solid waste dumpsite on the physicochemical qualities of groundwater during wet and dry seasons in Aba, Abia State, Nigeria. The physicochemical results revealed that the groundwater collected in the study areas showed some tested physicochemical parameters did not conform to water quality standards. The results of the present investigation portray potential danger to human health. The study also revealed that the physicochemical quality of the groundwater potentially varies with season. However, few of the parameters were still within the WHO and NSDWQ permissible limit as at the period the study was conducted. The study equally revealed that the parameters in the studied samples were influenced more by geophysical factors than the waste dumpsite. However, the need for the location of solid waste dumpsites away from residential areas is advocated as it is expected that over time, the impact of the waste dumpsite will be felt in the quality of groundwater in the areas studied.

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