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Comparative Analysis of Physicochemical Parameters in Surface and Groundwater Sources Around a Hospital in Agbarho, Nigeria

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ABSTRACT

An evaluation of the surface and groundwater sources near a general hospital in Agbarho,Ughelli North L.G.A., Delta State, Nigeria, was conducted. Water samples were taken from eight locations (S1, S2, S3, S4 and control) for surface water and (U1, U2, U3, U4 and control) for groundwater in the study area. The physicochemical properties of the water samples were tested using the method outlined by APHA, 1998. The dissolved oxygen levels (1.03-1.50 mg/L) were below the World Health Organization (WHO) standard for aquatic life, suggesting inadequate support for aquatic organisms. The turbidity levels (3.1-9.70 NTU) surpassed the acceptable limits set by the WHO. All other physicochemical parameters (pH from 6.30 to 7.70, electrical conductivity from 43 to 820 µS/cm, sulphate from 1.20 to 6.90 mg/L, nitrate from 3.00 to 18.90 mg/L, phosphate from 0.10 to 3.30 mg/L, biochemical oxygen demand from 0.13 to 0.80 mg/L, chemical oxygen demand from 1.10 to 6.70 mg/L, and temperature from 24 to 27ºC) were below the WHO acceptable limits. The control results fall within the WHO acceptable limits for all the parameters except for sulphate and nitrate that were below the WHO recommended standard. This research indicated that hospital waste and other human activities negatively affect water quality. It is recommended that the hospital in Agbarho, Delta State. Nigeria, strictly adheres to regulations on waste disposal and management.

Keywords: Physicochemical, Agbarho, hospital, surface water, Groundwater

INTRODUCTION

Water is essential for life [1]. A sufficient supply of clean and drinkable water is a fundamental requirement for all humans on Earth. The primary sources of fresh water are ground and surface water. These freshwater sources face threats from overuse, poor management, and pollution [2]. Water is one of the most crucial natural resources and is often referred to as the elixir of life. It makes up about 70% of the body weight of nearly all living organisms. Life cannot exist on this planet without water. It serves as a medium for both chemical and biochemical reactions [3]. Many living organisms inhabit in water. The basic needs of a society depend on water; for cleaning, public consumption, industrial processes, and cooling gas turbines for electricity generation. Groundwater accounts for 20% of the freshwater available [4, 5].

The importance of groundwater lies not only in its widespread occurrence and availability but also in its consistently good quality, making it an ideal source for drinking water [6,7]. However, groundwater resources are significantly threatened by the increasing interest in mechanized farming, rising population density, rapid urbanization, and effluent discharge from industries and healthcare facilities [8-10]. Groundwater supplies can sometimes be unsustainable due to low water productivity from its sources, poor water quality and occasionally hand-dug wells dry up after extended droughts.

Water pollution refers to any chemical, physical, or biological alteration in the quality of water bodies like lakes, rivers, oceans, and groundwater caused by human activities, either directly or indirectly [11]. Water pollution (both surface and ground) may be seen as a naturally occurring change in water quality or conditions caused directly or indirectly by human activities, making it unsuitable for food, human health, industry, agriculture, or recreational activities [12-14].

Wastewater generated by hospitals is commonly known as hospital waste, which is classified as a distinct category of waste encompassing all biological and non-biological materials discarded from hospitals and healthcare facilities, intended for no further use [15,16]. Hospital effluents contain both organic and inorganic components, including pathogenic microorganisms, hazardous chemicals, radioactive substances, and heavy metals. The presence of these elements in effluents, particularly in significant quantities, can pose serious risks to the population [17,18]. The volume of wastewater released from hospitals varies significantly among different institutions [19-21]. The health hazards associated with hospital wastewater for both terrestrial and aquatic ecosystems include the contamination of surface and groundwater, the accumulation of toxic non-biodegradable hospital waste products, the buildup of heavy metals, unregulated landfills, and inadequate sorting of waste materials [22]. The toxic substances released into water bodies are likely to bioaccumulate through the food chain [23,24]. Nevertheless, various countries are establishing systems for the comprehensive management of hospital effluents. For instance, all healthcare facilities in Greece are mandated to develop and implement a thorough management strategy to protect public health and the environment [25]. Conversely, some nations, particularly those in the developing world, have yet to enact legislation aimed at mitigating the environmental impacts of hospital effluents.

In Nigeria, numerous healthcare centers and hospitals lack effluent treatment facilities, leading to untreated waste being either disposed of on land or released into adjacent water bodies, which can result in significant health issues for local communities [26, 27]. Such hospital wastes can exert effects even at minimal concentrations. For example, an aquatic organism shows adverse reactions to low levels of formaldehyde, a common contaminant found in hospital effluents [28]. It has been reported that formaldehyde concentrations ranging from 10 to 100 mg/l are harmful to the microorganisms utilized in wastewater treatment systems [29]. Odiete [27] carried out similar research work on physicochemical and microbial analysis of borehole water in hospitals around Benin City, Nigeria. His main findings were the presence of microorganisms in all water samples from the hospitals, indicating contamination. He also observed the presence of diseases causing-bacteria like *salmonella* sp. and *E. coli* which poses health risks, necessitating water treatment.

The aim of this study is to examine the physicochemical parameters of surface and ground water sources located in the vicinity of a general hospital in Agbarho. The physicochemical parameters analyzed include temperature, conductivity, pH, sulfate, nitrate, phosphate, turbidity, dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) of the surface and ground water samples collected from the study area.

MATERIALS AND METHODS

Description of the Study Area

The hospital in Agbarho, in ughelli North Local Government Area is situated in the Delta Central senatorial district. Agbarho falls under the jurisdiction of the Ughelli North Local Government area in Delta State, Nigeria. This region is positioned between longitudes 3°E and 9°E, and latitudes 4°30’N and 5°21’N [30]. The delta area is characterized by frequent precipitation, with annual rainfall varying from 3500 to 4000 mm [31]. The combination of high rainfall, humidity, and river discharge during the rainy season, along with the low, flat terrain and poorly drained soils, leads to significant flooding. The climate in Agbarho adheres to a tropical pattern, with the rainy season extending from early February to late November, typically lasting between nine (9) to ten (10) months, and featuring a break in rainfall from late July to mid-August (commonly referred to as the August break). The dry season occurs from late November to early or mid-February [32]. The land in Agbarho is predominantly inhabited by the Urhobo ethnic group, which constitutes the majority ethnic group in Delta State and ranks as the fifth largest ethnic group in Nigeria. The Urhobo people are known for their friendliness and hospitality. Agbarho, being a significant socio-economic hub in the delta area, has attracted individuals from various other tribes, including the Hausa, Yoruba, Igbo, Tiv, as well as smaller tribes from Nigeria and neighboring countries such as Togo, Ghana, and the Benin Republic, among others. Researchers have focused on this area for various reasons in recent decades.

Source of Samples

The initial fieldwork aimed to identify the sample areas and points surrounding the hospital in Agbarho. Sample points were selected randomly [33] within the study area. The research samples utilized for this investigation were gathered from August to December 2024 from the designated study region, that is, the vicinity of a general hospital at Agbarho, in Ughelli North L.G.A., Delta State, Nigeria.

Pre-treatment

To achieve expected results, appropriate pre-treatment procedures for water samples were implemented to eliminate potential contamination (pollution) of the collected rainwater samples [34]. The sample containers underwent cleaning, washing, and rinsing with dilute nitric acid (HNO_3), followed by air drying for 10 hours. The sample containers were labeled to facilitate effective record-keeping. Rainwater samples collected in reservoir were labeled as S1, S2, S3, and S4, while those from groundwater were designated as U1, U2, U3, and U4, respectively.

Collection of Surface and Groundwater Samples

Random sampling techniques were employed throughout this study [35]. A total of eight samples were collected over a four-month period, from August to December 2024, across eight different sites within the study area.

Surface water samples from the reservoirs around the hospital were collected from four designated sampling points, S1, S2, S3, and S4. This terrain is characterized by low-lying, generally flat land that slopes gently southward. The hospital requires a substantial daily water supply. The water is sourced from mainly underground sources, except from the reservoir. However, the water from this source is not always routinely disinfected, which can pose a public health concern. The sampling point is about 0.5 km away from the general hospital.

The samples were collected after shaking the reservoir water body within aerated vessels with a bailer (water sampler) before fetching 500 cm^3 of surface water for analysis from each sampling point [36]. The surface water samples intended for physicochemical analyses were gathered in clean, sterile containers.

Groundwater samples were collected from four sampling points, U1, U2, U3, and U4. These points consisted of hand-dug wells located within the small farming community in the study area. A 500 cm^3 groundwater sample was collected from each sampling point.

The control sample was collected from a tap, about 1 km away from the hospital.

Both surface and groundwater samples were gathered in 250 cm^3 bottles with stopper. One millimetre each of Winkler's solutions A and B was added to the samples on site to stabilize the oxygen [37].

The samples were collected and transported to the laboratory for analysis within 24 hours of their collections. They were tested for dissolved oxygen, chemical oxygen demand, and biochemical oxygen demand for both surface and groundwater samples.

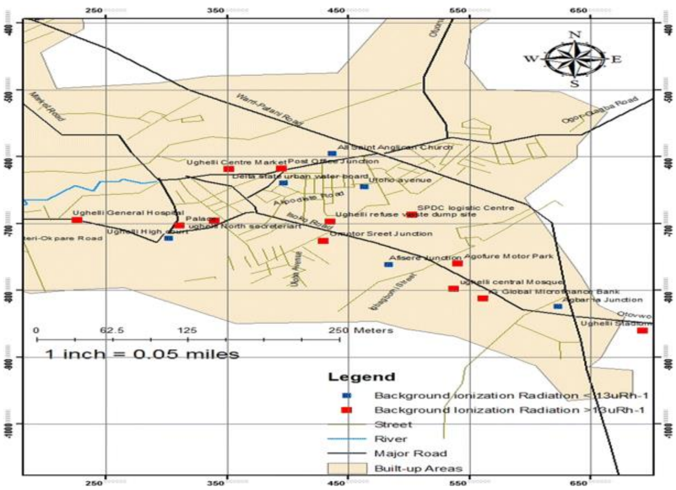

Figure 1. Agbarho/ Ughelli map showing the study area and the hospital

Analysis of Physicochemical Parameters

To assess the quality of the harvested water samples, the standard methods for the examination of water and wastewater protocol were followed [38]. The physicochemical parameters, including temperature, pH, turbidity, and electrical conductivity, were measured using standard methods for water and wastewater analysis. The chemical parameters evaluated included total Hardness, total alkalinity, biochemical oxygen demand, chemical oxygen demand, dissolved oxygen, nitrate, sulphate, and phosphate.

Dissolved oxygen was determined by Winkler method, chemical oxygen demand was determined using the open reflux method, biochemical oxygen demand was tested by iodometric method, the determination of sulphates was conducted by turbidimetric method, the nitrate was analyzed by UV spectrophotometric screening method, the determination of phosphate was carried out by spectrophotometer method, turbidity was analyzed by nephelometric method, electrical conductivity was determined using a conductivity meter, the pH of water sample was analyzed via a pH meter, whereas the temperature of water samples was measured with a thermometer [8].

Statistical Analysis

Analysis of variance (ANOVA) was used to conduct a test of significance at $p<0.05$, in order to assess the difference between the parameters at each sampling point. Correlation matrix was obtained for all parameters in each sampling point so as to establish the relationship between them.

RESULTS AND DISCUSSION

The average concentrations of the physicochemical parameters of the surface water are displayed in Table 1.

Table1: Physicochemical Parameters of Surface Water

PARAMETER	Site S1	Site S2	Site S3	Site S4	Control
pH	7.25±0.01	6.90±0.01	7.70±0.01	7.35±0.02	7.50±0.04
E.C (μS/cm)	75.00±1.00	74.00±1.00	820.00±1.00	701.00±1.00	881.00±1.20
DO (mg/L)	1.03±0.10	1.40±0.10	1.10±0.10	1.10±0.01	3.10±0.03
BOD (mg/L)	0.23±0.10	0.20±0.10	0.80±0.10	0.40±0.12	4±0.3
COD (mg/L)	1.10±1.53	3.10±1.00	3.71±1.00	1.72±1.53	9±2.53
Turbidity (NTU)	3.10±0.12	3.90±0.02	9.70±0.01	7.00±0.01	4.50±0.4
Nitrate (mg/L)	3.00±0.20	9.10±0.02	3.50±0.10	5.90±0.10	10.90±2.10
Sulphate(mg/L)	3.90±0.10	6.50±0.10	2.30±0.20	2.50±0.20	20.50±5.20
Phosphate (mg/L)	1.00±0.10	0.90±0.10	3.30±0.10	3.10±0.10	1.10±0.01
Temperature (°C)	24	22	24	26	19

Values are mean± SD of the physico-chemical parameters of the surface water samples. °C- degree centigrade, μohms/cm-micro-ohms per centimeter, NTU-Nephelometric turbidity units, mg/L- milligramme per litre

Table 2 presents the correlation matrix between the various parameters in the surface water sites, whereas Table 3 shows the correlation matrix between the various parameters in the groundwater sample sites.

Table 2: Correlation Matrix among Surface Water Samples

Parameter	pH	EC	DO	BOD	COD	Turbidity	Nitrate	Sulphate	Phosphate	Tempt
pH	1.000									
EC	0.831	1.000								
DO	-0.670	-0.331	1.000							
BOD	0.896	0.881	-0.272	1.000						
COD	0.234	0.373	0.543	0.628	1.000					
Turbidity	0.844	0.949	-0.199	0.976*	0.615	1.000				
Nitrate	-0.764	-0.321	0.936	-0.431	0.289	-0.300	1.000			
Sulphate	-0.910	-0.834	0.795	-0.706	0.099	-0.714	0.738	1.000		
Phosphate	0.821	0.998**	-0.362	0.851	0.313	0.926	-0.329	-0.853	1.000	
Tempt	0.558	0.641	-0.741	0.296	-0.467	0.418	-0.469	-0.762	0.690	1.000

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

Some of the parameters were found to bear statistically high correlation with each other indicating close association of these parameters with each other. The electrical conductivity and the levels phosphate in the water samples showed high positive correlation (0.998). Further positive correlations were observed between BOD and Turbidity; pH, BOD and turbidity; E.C, turbidity and BOD; DO and turbidity; BOD and phosphate; Turbidity and phosphate, an indication of influence of one parameter on the other. Sulphate showed negative correlation with all parameters except DO, COD and nitrate. Nitrate also showed negative correlation with all parameters except DO and COD. Hence, sulphate and nitrate may serve as useful indices of water quality of the surface water because with increase or decrease in the value of these parameters, nitrate and sulphate fall or rise.

Table 3: Physicochemical Parameters of Groundwater

Parameter	Site U1	Site U2	Site U3	Site U4	Control
pH	6.80±0.02	7.23±0.01	7.00±0.01	6.30±0.01	7.50±0.04
E.C (µS/cm)	62.00±1.00	44.00±1.00	49.00±1.00	43.00±1.00	881.00±1.2
D.O (mg/L)	1.40±0.10	1.13±0.10	1.20±0.10	1.50±0.10	3.10±0.03
B.O.D (mg/L)	0.50±0.20	0.13±0.10	0.13±0.10	0.30±.10	4±0.3
C.O.D (mg/L)	1.80±1.00	3.50±2.00	2.31±1.20	6.70±2.00	9±2.53
Turbidity (NTU)	6.00±0.01	7.40±0.01	7.20±0.01	5.70±0.01	4.50±0.4
Nitrate (mg/L)	3.40±0.20	13.70±0.10	18.90±0.10	16.40±0.10	10.90±2.10
Sulphate (mg/L)	1.90±0.10	6.90±0.10	1.20±0.10	1.50±0.20	20.50±5.20
Phosphate (mg/L)	0.10±0.00	1.40±0.20	0.60±0.12	0.40±0.10	1.10±0.01
Temperature (°C)	25	26	25	27	19

Values are mean± SD of the physico-chemical parameters of the ground water samples.ºC- degree centigrade, µohms/cm-micro-ohms per centimeter, NTU- Nephelometric turbidity units, mg/l- milligramme per litre

Table 4 presents the correlation matrix between the various parameters in the groundwater samples.

Table 4: Correlation Matrix among groundwater Samples

Parameter	pH	EC	DO	BOD	COD	Turbidity	Nitrate	Sulphate	Phosphate	Tempt
pH	1.000									
EC	0.652	1.000								
DO	-0.581	0.232	1.000							
BOD	0.000	0.740	0.763	1.000						
COD	-0.990**	-0.716	0.489	-0.068	1.000					
Turbidity	0.538	-0.288	-0.988*	-0.829	-0.457	1.000				
Nitrate	-0.440	-0.837	-0.271	-0.824	0.448	0.392	1.000			
Sulphate	0.182	-0.346	-0.683	-0.429	-0.042	0.587	-0.043	1.000		
Phosphate	0.073	-0.642	-0.821	-0.798	0.055	0.792	0.411	0.885	1.000	
Tempt	-0.938	-0.734	0.381	-0.091	0.976*	-0.379	0.368	0.164	0.203	1.000

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

With COD and temperature showed high positive correlation (0.976). COD and pH showed high negative correlation (-0.990). Turbidity and DO also showed high negative correlation (-0.998). This implies that an increase in one leads to a decrease in the other.

In this research, eight samples of surface water and groundwater were gathered. The samples were sourced from eight locations (S1, S2, S3, S4, U1, U2, U3, and U4), all situated in the vicinity of a hospital in Agbarho. The levels of parameters of all control samples fell within the recommended WHO standard except for sulphate and nitrate that fell below WHO recommended standard of 250 mg/L and 50 mg/L for suphate and nitrate respectively. The highest pH level recorded at the surface water sites was 7.70, which exceeds the range of 6.20-6.88 documented by WHO [39] regarding the physicochemical parameters of hospital effluent from a university teaching hospital located in southern Nigeria.

The ANOVA indicated that pH levels varied significantly (at $p<0.05$). All locations within the study area complied with the WHO (2011) permissible guideline value of 6.5-8.5 [39].

The conductivity values obtained in this study revealed that the surface water samples contained a considerable amount of dissolved ions (75.00-820.00 µS/cm), which was higher than that of the groundwater samples (43.00-62.00 µS/cm).

The elevated EC values observed at certain sites may be attributed to the presence of chemicals in ionic form within the effluent discharged into the surface water from the hospital's liquid waste treatment facility. The EC levels across all sites fell within the WHO (2011) recommended limit of 500-1500 µS/cm.

The turbidity values recorded at the groundwater sites (5.70-7.40 NTU) were lower than the 9.7 NTU noted for surface water site S3. Consequently, the surface water sites were more turbid than the groundwater sites. This may be due to the open nature of the surface water, which facilitates the influx of impurities that can obstruct light penetration. The difference in mean turbidity values was not statistically significant at a confidence level of $p<0.05$. All sites in the study area, with the exception of S1 and S2, exceeded the WHO (2011) permissible turbidity levels of 5 NTU [39].

The dissolved oxygen values recorded in the surface water sites (1.03-1.40 mg/L) and groundwater sites (1.13-1.50 mg/L) were lower than the range of 6.21-19.78 mg/L reported by Ibeh and Omoruyi [18] concerning the physicochemical parameters of hospital effluent from a university teaching hospital in southern Nigeria. All values recorded were below the permissible limits of 5 mg/L set by the WHO (2011). This suggests that both surface and groundwater sources are contaminated. A tropical aquatic ecosystem requires a dissolved oxygen concentration of at least 5 mg/L to sustain a diverse range of biota, including fish [40]. The DO values did not exhibit any significant variation across the sampling locations.

The biochemical oxygen demand values measured in this study ranged from 0.13 to 0.50 mg/L. This range is considerably lower than the 43.77 to 235.64 mg/L reported by Obruche et al [41] for the physicochemical parameters of hospital effluent from a university teaching hospital in southern Nigeria. There was no significant difference in the average BOD values of the surface water samples. All BOD values recorded in this study fell below the WHO (2011) permissible guideline of 6 mg/L.

The chemical oxygen demand values obtained in this study varied from 1.10 to 6.70 mg/L. The maximum value of 6.70 mg/L was recorded at site U4, while the minimum value of 1.10 mg/L was noted at site S1. This is lower than the range of 181 to 290.33 mg/l observed by Obruche et al [42] for effluents released from the liquid waste treatment facility of the Ahmadu Bello University Teaching Hospital in Zaria, Nigeria. All values obtained in this study were below the 10 mg/L threshold established by the WHO (2011) as the permissible limit.

Nevertheless, the COD values were generally higher than the BOD values, as the test oxidizes materials such as fats and lignins, which are not easily biodegradable. The increase in COD values is attributed to the presence of oxidizable organic matter [43]. The differences in the mean COD values of the surface water samples were not significant according to the analysis of variance.

High nitrate levels (>1 mg/L) are detrimental to aquatic life. The nitrate levels recorded in this study ranged from 3.00 to 9.10 mg/L for surface water sites and from 3.40 to 18.90 mg/L for groundwater sites. Analysis of variance showed that COD varied significantly ($p < 0.05$) across the sampling sites. The highest nitrate concentration of 18.90 mg/L was recorded at site U3, which is lower than the 30.00 mg/L reported by Heah et al [43] for effluents from the liquid waste treatment plant at Ahmadu Bello University Teaching Hospital in Zaria, Nigeria. The difference in average nitrate levels between the studies was not statistically significant. All nitrate measurements in this study were below the WHO (2011) guideline limit of 50 mg/L [39].

Phosphate levels in surface water ranged from 0.90 to 3.30 mg/L, while groundwater samples had concentrations between 0.10 and 1.40 mg/L. Phosphate is a notable pollutant when present in large amounts because it encourages algae growth, which can lead to eutrophication issues [43]. Although high phosphate concentrations are not considered a direct health risk (WHO, 2011), they contribute to water body eutrophication. The mean phosphate levels showed no significant variation.

Sulfate concentrations in surface water samples ranged from 2.2 to 6.5 mg/L, and groundwater samples ranged from 1.2 to 6.9 mg/L. While there is no health-based guideline for sulfate, authorities should be alerted if sulfate levels exceed 500 mg/L due to possible gastrointestinal effects. Sulfate can also affect water taste and contribute to corrosion in water distribution systems [39]. No significant difference was found in the average sulfate concentrations.

Surface water temperatures ranged from 22 to 26°C, and groundwater temperatures ranged from 25 to 27°C. Water temperature itself does not pose direct health risks [44].

Analysis of variance (ANOVA) showed that pH varied significantly (at $p<0.05$) across the sampling sites. The pH varied between 6.90 and 7.70 across the sites. Generally, the pH of the samples tended to be slightly alkaline among the sites except for samples S2 where the pH was slightly acidic.

Electrical conductivity varied between 74.00 µS/cm (S2) and 820.00 µS/cm (S3) as shown in Table 2. The dissolved oxygen values varied between 1.03 mg/L (S1) and 1.40mg/L (S2). The DO values showed no significant difference across the sampling points. The biochemical oxygen demand fluctuated between 0.20 mg/L at S2 and 0.80 mg/L at S3. There was no significant difference in the mean B.O.D values of the surface water samples. The difference in the mean COD values of the surface water samples were not significant using analysis of variance. The turbidity of the samples varied between 3.10 NTU (S1) and 9.70 NTU (S3). The difference in the mean turbidity values was not significant at a confidence limit of $p<0.05$. The mean nitrate concentration was found to vary between 3.00 mg/L (S1) to 9.00 mg/L (S2). The difference in the mean nitrate values was not significant. Sulphate was found to vary between 2.30 mg/L and 6.50mg/L across the surface water sites. There was no significant difference in the mean of the sulphate concentration. The phosphate concentrations in the surface water sites were found to vary between 0.90 mg/L and 3.30 mg/L. The mean phosphate values were not significant.

CONCLUSION

This study examined various water quality parameters including pH, turbidity, electrical conductivity, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, nitrate, sulfate, phosphate, and temperature in both surface and groundwater samples. The dissolved oxygen levels were found to be below the WHO standards for aquatic life, which could threaten organisms living in the area. Turbidity levels also exceeded the WHO's allowable limits, while all other measured parameters remained within acceptable ranges. Correlation analysis indicated that nitrate and sulfate could be effective indicators of water quality in surface water. Based on these findings, it is recommended that government authorities implement and enforce stricter regulations on waste disposal and management in the region.

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