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A Comparison of Rainwater in Ondo State, Nigeria to FME Approved Drinking Water Quality Standard

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Abstract: Between the months of March and December, (2005) rainwater samples were randomly collected from different parts of Ondo State, Nigeria in comparison to FME drinking water quality. The rainwater samples were analysed for microbiological and physicochemical values. This is to know the safety level of the water and the danger(s) it poses to the consumers who have no access to quality pipe borne water sources. The microbial load recovered during early rains, peak and termination of rainfall ranged between 5.05-6.71; 0.05-1.04 and 2.95-4.02 log cfu (m⁻¹), respectively. Fungal counts in that order was 1.3-2.2; 0.00 and 1.00-1.5 log spore (m⁻¹), respectively. The following organisms were isolated and identified as bacteria genera: *Shigella dysenteriae*, *Bacillus cereus*, *Klebsiella* sp., *Escherichia coli*, *Branhamella catarrhalis*, *Aerococcus aerogenes*, *Staphylococcus epidermidis* and *Streptococcus faecalis* while *Aspergillus niger*, *Cladosporium* sp., *Microsporium canis*, *Geotrichum albidum* and *Saccharomyces* sp. as fungal species. The conductivity SO₄²⁻ and TDS values in the rainwater samples were less than the allowable values while the pH, CO₃²⁻, NO₃ and MPN were more than the allowable values in good quality water as approved by FME and WHO standards. This signifies that consumption of rainwater in this particular area is not safe as this may pose a health risk among consumers of this water.

Key words: Rainwater, evaluation, microbiological, physicochemical, Ondo state, Nigeria

INTRODUCTION

Water plays a significant role which cannot be overemphasized as it is of fundamental importance to all kinds of plants and animals. The availability of quality water dictates the quality of life since water is a basic requirement of life. Although there is the campaign by WHO that pipe borne treated water should be used for both domestic and irrigation purposes because of the large population of the world especially in the developing nations, rainwater is one of the major sources of water that the people depend on especially those living in rural communities and even urban areas where pipe borne water is not available.

However, rainwater may serve as a source of infection to the consumers because airborne pathogenic bacteria present in the air might come down with the collected rainwater for domestic use. Water in its natural state may not be pure because it is a universal solvent with the ability to dissolve numerous chemicals and to carry a lot of impurities in suspension (Rim-Rukeh *et al.*, 2005) in a community water supplies, test for physical and chemical qualities are the two most important types of analyses because water supply systems are vulnerable to infections. From the tests the types and levels of contaminants present in the water supply must be treated, this information is essential because the aim of water analysis is to remove any contamination present, as to determine the need

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for and level of treatment (Nwaiwu and Olanrewaju, 2005). Since water is very essential especially for domestic purposes and the use of rainwater is a common practice in most homes in both urban and rural areas where portable water supply is a problem and that this water can serve as source of infection (Twort, 2002; Chao *et al.*, 2004) this study is aimed therefore at evaluating the microbial quality and physicochemical properties of rainwater being collected for domestic use in this part of the country (Ondo State), Nigeria in comparison to FME drinking water quality standard to evaluate the type of dangers such water pose to the health of the consumers or users.

MATERIALS AND METHODS

Sample Collection

Ondo State of Nigeria occupies an area of about 20,595 km² lying between 4°30' and 6°00' east of Greenwich meridian and latitude 5045' and 80 15' north of the equator and fall under a rain zone of 1200 mm annually.

Rural and urban areas of the four geographical zones of the state were the areas of study between March to December, 2005. In the zones of study, three different stands of 6 ft above ground level were mounted randomly in which two hundred and fifty milliliter polypropylene sampling bottles were clamped only during rain. The sampling bottles were allowed to be filled up to the brim to trap air, then tightly covered and taken to the laboratory for analyses within 2 h.

Microbiological Analysis

The collected rainwater samples were subjected to Most Probable Number (MPN) multiple tube techniques test for coliform bacteria. The tubes were incubated at 37°C for 24-48 h for coliform bacilli. Positive tubes were then subcultured into eosin methylene blue agar for confirmation of *Escherichia coli*. Also Salmonella/Shigella agar was used for the detection of *Salmonella*, *Shigella* sp. Nutrient agar was used for the detection of other bacteria species and Malt extract agar was used for isolating mold and yeast species. To estimate the number of heterotrophic bacteria in the rainwater samples, the criteria of Anonymous (1985) was used after serial dilution. Plates were incubated aerobically at 28±1°C for 5 days. The resultant colonies were enumerated with colony counter (Gallenkamp). The colonies that were culturally with slightest difference were purified by subculturing into freshly prepared nutrient agar. The pure bacterial isolation were identified with the criteria of Holt *et al.* (1994), yeasts were identified with the criteria of van Rie (1984) and moulds identified according to the methods of Rhode and Hartman (1980).

Nitrate (NO₃⁻) Determination

Fifty milliliters filtrate of rainwater samples was added to 1 mL concentrated HCl solution and mixed thoroughly by agitating with Stuart flask shaker for 5 min. The calibration standards of between 0-7 mg L⁻¹ was prepared. The following volumes of intermediate nitrate solutions (1,2,4,7.....35 mL) was used. A wavelength of 230 nm was used to read nitrate using a spectrophotometer (Pharmacia Biotech, model 80-2088-64). Absorbance was read against distilled water used as the blank at 0. Nitrate concentration of the sample were obtained from the standard curve.

Carbonate (CO₃²⁻) Determination

Carbonate concentration in the rainwater samples was detected by titration method. In a 100 mL capacity conical flask, 10 mL of rainwater samples was measured and two drops of phenolphthalein indicator was added. The resultant pink colour water solution was titrated with 0.02 M sulphuric acid to a colourless neutralization end point. This was however calculated to obtain the carbonate values in the rainwater samples.

pH Determination

Twenty milliliters, of the rainwater samples was dispensed into clean 50 mL capacity beaker and the pH values was determined with (Extich instrument pH meter) after standardizing with buffer 4.0 and 7.0 solutions.

Sulphate (SO_4^{2-}) Determination

This was obtained from the water samples by turbidometric method. The glass cuvette of spectrophotometer (Pharmacia Biotech, Model 80-2088-64) was filled with the rainwater samples. Absorbance (Concentration) was read with calibration curve.

Total Dissolved Solids (TDS) and Conductivity Determination

These two parameters were determined with a bench-top multiparameter water quality instrument (Orion 1260 after calibration. All methods of sample analysis were consistent with the standard methods of APHA (1990), ASTM (1986) and DPR 2002.

RESULTS

Microbiological Analysis

The microbial load in the rainwater samples varied with the period of collection. During the early rains which marked the end of dry season, a very high microbial load was observed in the samples from all the collection centers. The months of March through May have higher bacterial load significantly different over the fungal load. This signifies that the prevailing bacterial cells present in the atmosphere at this period was more than the fungal spores (Table 1). From the months of June through September (peak of rain), bacterial load was lower than observed in the early and termination of rain. However, no fungal load was recorded at this period. The constant high humidity and moisture would not have allowed the much growth of fungal on substances and their abundance suspension in the atmosphere at this period, hence high moisture is not always in good support of fungal growth. The months of October through December (termination of rain) experienced irregular rain fall and this irregularities in rain fall brings about dryness and accumulation of impurities in the atmosphere thus the gradual increase observed in the microbial load (Table 1). However, bacterial load in the early, peak and termination of rain were between 5.21-6.71, 1.05-1.18, 3.13-4.21 log CFU (m^{-1}), respectively. This increase and decrease status observed in the bacterial load took the same pattern in fungal load, therefore the prevailing dust and other particles accumulation in the atmosphere due to drought regulates microbial suspension in the atmospheric space that come down along with rain drop.

The Most Probable Number (MPN) coliforms in the rainwater samples also varied with the periods of the samples collection in the four geographical zones. The highest coliform count removed was recovered in the rainwater samples from the South zone followed by North, East and West zones, respectively. However, the MPN results as shown in Table 2 signifies that none of the collected water samples satisfied the FME and WHO standard for portable drinking water. Eight bacterial species were characterized and identified as *Shigella dysenteriae*, *Bacillus cereus*, *Klebsiella* sp., *Escherichia coli*, *Branhamella cattarhalis*, *Aerococcus aerogenes*, *Staphylococcus epidermidis* and *Streptococcus faecalis*. The fungal species identified are *Aspergillus niger*, *Cladosporium* sp. *Microsporum canis*, *Geotrichum albidum* and *Saccharomyces* sp.

Physicochemical Analysis Conductivity

The conductivity of the rain water go along with the trend in rain fall. The higher the rain the less electric conductivity of the samples in the four geographical zones studied. This amount of electrical current supported (conductivity) by the samples is proportional to the concentration of charged particles present in the water samples. During the period of study, it was found higher in the early rains (March-May) followed by termination of rain (October-December) (Table 3-6).

Table 1: Trend of microbial load in the rain water (counts as log₁₀)

Months	Bacterial count	Fungal count
March	6.71	1.35
April	6.44	1.35
May	5.21	2.12
June	1.05	-
July	0.41	-
August	1.18	-
September	1.18	-
October	3.24	1.07
November	3.13	1.00
December	4.21	1.20

Table 2: MPN of rainwater samples from the four zones studied in Ondo State, Nigeria

Months	Samples	East	South	West	North
March	1	10	180+	9	100
	2	10	180+	9	150
	3	10	15	9	2
	4	9	17	9	14
April	5	9	20	7	4
	6	8	15	6	20
	7	10	17	10	20
	8	8	20	10	10
May	9	8	22	10	15
	10	9	30	9	26
	11	8	180+	9	100
	12	7	180+	10	150
June	13	2	20	7	20
	14	2	20	7	15
July	15	0	17	6	10
	16	0	15	5	12
	17	0	9	6	10
	18	0	10	5	11
	19	0	12	2	10
	20	0	15	2	9
August	21	0	10	1	8
	22	0	10	2	8
	23	0	9	1	7
	24	0	9	1	6
September	25	2	10	0	5
	26	1	8	0	5
	27	2	10	0	8
	28	1	10	0	9
October	29	4	20	1	8
	30	5	17	2	8
	31	5	35	6	8
	32	5	40	6	8
November	33	4	180+	5	90
	34	6	180+	5	70
	35	6	24	8	12
	36	7	20	9	15
December	37	7	20	10	10
	38	7	20	6	10
	39	8	17	7	10
	40	7	20	8	10

pH

Increase in the pH values was observed during the peak of rain in the area of study. The periodic variation in pH as observed, was in sequential trend of rain fall whereby acidic content in the samples was observed during the early rain (Table 3-6).

Table 3: Mean±SD of physicochemical parameters of rain water in Ondo State North

Parameters	Early rain (March-May)	Peak of rain (June-Sept)	Termination of rain (Oct-Dec)
Conductivity ($\mu\text{S cm}^{-1}$)	22.3±2.23	22.1±2.04	22.1±2.08
pH	5.4±0.13	6.5±0.26	5.5±0.18
CO_3^{2-} (mg L^{-1})	15.78±1.05	16.77±1.11	14.98±1.44
NO_3 (mg L^{-1})	17±3.12	22±5.42	13.92±3.16
SO_4^{2-} (mg L^{-1})	2.01±0.02	1.25±0.00	1.30±0.00
TDS (mg L^{-1})	19.75±2.41	18.10±1.36	12.38±1.12

Table 4: Mean±SD of physicochemical parameters of rain water in Ondo State West

Parameters	Early rain (March-May)	Peak of rain (June-Sept)	Termination of rain (Oct-Dec)
Conductivity ($\mu\text{S cm}^{-1}$)	21.5±2.65	20.3±2.14	21.1±2.03
pH	5.5±0.17	6.5±0.24	5.6±0.15
CO_3^{2-} (mg L^{-1})	15.63±1.60	16.68±1.10	14.92±1.40
NO_3 (mg L^{-1})	17±4.11	22±4.96	12.90±3.00
SO_4^{2-} (mg L^{-1})	2.04±0.02	1.18±0.00	1.30±0.02
TDS (mg L^{-1})	19.75±2.40	18.10±1.36	12.36±1.13

Table 5: Mean±SD of physicochemical parameters of rain water in Ondo State East

Parameters	Early rain (March-May)	Peak of rain (June-Sept)	Termination of rain (Oct-Dec)
Conductivity ($\mu\text{S cm}^{-1}$)	22.1±3.14	20.6±2.10	21.3±2.14
pH	5.4±0.13	6.8±0.18	5.5±0.18
CO_3^{2-} (mg L^{-1})	15.71±1.65	16.70±1.18	14.96±1.35
NO_3 (mg L^{-1})	17±4.08	21±5.86	12.83±3.05
SO_4^{2-} (mg L^{-1})	2.02±0.00	1.24±0.01	1.26±0.00
TDS (mg L^{-1})	19.86±2.55	19.20±1.28	12.38±1.25

Table 6: Mean±SD of physicochemical parameters of rain water in Ondo State South

Parameters	Early rain (March-May)	Peak of rain (June-Sept)	Termination of rain (Oct-Dec)
Conductivity ($\mu\text{S cm}^{-1}$)	22.5±552.06	20.8±2.11	22.3±2.01
pH	5.4±0.12	6.4±0.20	5.5±0.15
CO_3^{2-} (mg L^{-1})	15.78±1.58	16.76±1.14	14.99±1.45
NO_3 (mg L^{-1})	17±3.14	22±4.88	13.72±3.11
SO_4^{2-} (mg L^{-1})	2.05±0.00	1.20±0.00	1.30±0.01
TDS (mg L^{-1})	19.65±2.48	19.19±1.40	12.49±1.16

Carbonate

Rain water samples at termination of rain (Oct-Dec) had less mean carbonate value than samples observed at early and peak of rain. Hence mean carbonate value in the rain water was higher during the peak of rain (June-Sept) with above 1.00 and 2.00 mg L^{-1} over early and termination of rain, respectively, this signifies the abundance of carbonate concentrations in rain water during the wet season over the dry season (Table 3-6).

Nitrate

Nitrate concentration in the samples shows periodic variations which was higher at peak of rain with 22 mg L^{-1} in three out of the four geographical zones studied. Following this, is the early rain having 17 mg L^{-1} concentration but with significant different at (SD±3.12, 4.11, 4.08 and 3.14) respectively for North, West, East and South zones. However, the termination of rain witnessed a lower nitrate concentration and also with significant differences in standard deviation (Table 3-6).

Sulphate

Mean sulphate values in the rain water was higher in the early rain followed by termination of rain. Though there was periodic variation in sulphate concentration at early, peak and termination of rain, there was no significant periodic variation deduced from standard deviation ($SD \pm 0.00-0.02$) (Table 3-6).

Total Dissolved Solids Value

The total dissolved solids in the rainwater samples reduced alongside trend in rainfall. The four geographical zones had similar total dissolved solids values in the period of sampling with significant differences in standard deviation. The rain water sample from East and South zones were more concentrated in the TDS values than the rain water from North and West zones (Table 3-6).

The rain water samples in the chemical parameters observed, met the approved standard of quality drinking water while somewhere below the save limits specified for drinking water quality because of their higher concentrations than the approved standard (Table 7).

DISCUSSION

Rainwater is very essential especially for domestic purposes in places where access to clean and safe drinking water is still luxury. However from this study, one finds that rainwater is not all that hygienic especially for drinking and domestic purposes because from the different parameters looked at, the level of chemical, physical and microbial contaminations in the rainwater sampled fell short of the standards of portable water. The high microbial load recorded from the rainwater most especially during the early rains is an indication of presence of high organic matter dissolved in the rainwater samples which are usually the common features for natural and untreated water. The temperature (28°C) and time (5 days) of incubation could also be responsible for the bacterial counts recorded as it is a relative nature almost all bacteria can grow except the very strict psychrophiles and thermophiles; longer incubation period could as well enable slow growers in the water samples to adjust to the new environment and grow in the growth media.

E. coli is normally indicator of faecal contaminations of water (Collins *et al.*, 1995; Chao *et al.*, 2004) but based on the distance above the ground level in which the rainwater samples were collected, it is not likely that their presence in the samples is an indication of faecal contamination, but through particles carried in air current during rain storm. No matter what however, the presence of *E. coli* is worrisome because *E. coli* has been implicated as the cause of travellers diarrhoea and infant dysentery (Kirkwood, 1998; Twort *et al.*, 1985) as well as urinogenital tract infection in children. In addition, *E. coli* 0157: H7 serotype has been found to cause blood and non-bloody diarrhoea. Apart from *E. coli*, other pathogenic bacteria were as well identified from the same water samples. This aspect of the results obtained supports the statement of (Arvanitidou *et al.*, 1996) that the presence of *E. coli* gives an indication of a possible presence of pathogens.

Klebsiella pneumonia is found associated with pneumonia and other inflammations of the respiratory track (Humpheries, 1974). *Branhamella cattarhalis* is one of the organisms commonly

Table 7: Comparison of results obtained to FME 2002 approved drinking water quality characteristics

Parameters	North	South	East	West	FME 2002
Conductivity ($\mu\text{S cm}^{-1}$)	22.1-22.3	20.8-22.5	20.6-21.3	20.3-21.5	4000
pH	5.4-6.5	5.4-6.4	5.4-6.8	5.5-6.5	6.5-8.5
CO_3^{2-} (mg L^{-1})	4.98-16.77	14.99-16.76	14.96-16.70	14.92-15.68	<10
NO_3 (mg L^{-1})	13.92-22.00	13.72-22.00	12.83-21.00	12.90-22.00	10
SO_4^{2-} (mg L^{-1})	1.25-2.01	1.20-1.96	1.24-2.02	1.30-2.04	500
TDS (mg L^{-1})	12.38-19.75	12.49-19.65	12.38-19.86	12.36-19.75	400

present in nasopharynx and oropharynx of healthy humans. *Bacillus cereus* causes food poisoning that produces neurotoxins. *Staphylococcus epidermidis* has been implicated in bacterial conjunctivitis in adults.

The isolation of microorganisms from the rainwater samples proved it a significant medium and a carrier in the spread of diseases. Rainwater in such status can directly contaminate humans with its colonized microorganisms if used to wash salad vegetables, fruit or when drunk. The transfer of pathogenic microorganisms from the atmosphere by rainwater depends on the human activities generating total dissolved solids, method of waste disposal and decomposition; and industrialisation in an environment (Howard *et al.*, 1995). Before industrial revolution, man has been systematically polluting his environment with physical, chemical and microbial contaminations. These contaminations increase alongside population, industrialization, expansion of towns and productivity increase. It is therefore possible for rainwater to look crystal clear but could be implicated with microbial, chemical and physical contaminations by air current which is worldly known to be serving as a transport medium to most atmospheric pollutions (Frank *et al.*, 1981).

The acidic pH values could be as a result of conversion of chemical substances like carbon, nitrogen and others to sulphuric acid, nitric acid and carbonic acid in the atmospheric environment. Five milligram per litre is the maximum allowable carbonate values in any good quality water. Therefore, the excess carbonate values recorded in the rainwater samples can make water corrosive and can as well induce corrosion in metal materials not coated or prevented from constant drop of such water. This result obtained is in correlation with (Avwiri and Tay, 1999) who confirmed the corrosiveness of rainwater collected from gas flared location. The natural formation of nitrate by photochemical oxidation of nitrogen to give oxides nitrogen during lightning and thunder storms may have resulted to the high nitrate values obtained in the water samples. Excessive concentration of nitrate in drinking water has been implicated in infantile methemoglobinemia or the blue baby syndrome and is perhaps related to an increase risk in gastric cancer (Walter, 1987). The total dissolved solids though was far less than (FME, 2000) standard of quality water, the impurities and particles in the rainwater could support the increase of the chemical and microbial components, if stored for a long time. Impurities in water have been implicated for a majority of ill-health (Chauvin, 1991; Kirkwood, 1998). Heavy metals cause malfunction in human beings ranging from lungs to heart diseases. Organic matters give rise to bad taste and odor as they favored the development of algae, fungi, bacterial and provides malodorous compounds with chlorine (Revara, 1979).

And based on (FME, 2002) guidelines and standards for drinking water quality, carbonate and Nitrate mean values in the rainwater samples were more than the allowable values in good quality portable water. The pH of the sample was acidic in nature. Conductivity, sulphate and the total dissolved solid values of the rainwater samples were less than the allowable values in good quality water. Also the MPN of the rainwater samples throughout the period of study did not meet the WHO (1984) and (FME, 2002) standard of 0/100 mL in quality drinking water.

The prevailing activities occurring from local industries, uncontrolled refuse disposal, drying up of rivers, ponds at times regulated by negative ecological distribution could contribute immensely to the occurrence of the diverse chemical and microbial contaminations observed in the rainwater.

Hence all approach towards the achievement and maintenance of acceptable environment standards can not be totally met in any community and because policy of land use is not in practice in the area of study, chemical and microbial contaminations will almost be irreversible. However, the parameters employed in the rainwater samples evident the right information which decides the type of treatment to make the rainwater good enough for consumption. Also environmental pollutions that contaminate rainwater can not be totally controlled most especially in the area of study where the knowledge of proper wastes disposal and danger of chemical substances in the atmosphere is lacking. Environmental degradation in form of water pollution is essentially economic problem, more so that

it is a by-product of production and consumption activities. Water contamination is one of the impact of environmental problems faced by various urban and rural centers in the developing countries. However, the ignorant alteration by man of chemical, physical and biological quality of the environment could immensely contribute to this. So to be out of this problem of little or no portable drinking water in urban and rural communities, the chemicals, physical and biological study of available water sources is of paramount importance for establishing a campaign and creating the awareness of possible cautions to minimize environmental pollution that could contaminate sources of water to reduce the incidence of water bone diseases.

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