Spatial Variation of Physicochemical Parameters of Rainwater Harvested in Some Communities of Niger Delta Due to Different Exposure to Atmospheric Condition

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Abstract

This study was carried out to assess the effect of altered atmospheric condition on the physicochemical parameters of rainwater samples from Trans-Amadi, Rumuolumeni and Diobu all in Rivers State of Niger Delta. Rainwater samples from the three different locations were harvested directly using pre-sterilized plastic bottles within the same period of time. Each sample collected was divided into three parts. The samples were analyzed by comparing them with WHO standards for drinking water. A part was analyzed within 6 hours of sample collection, the second part was kept in a darkroom for a period of 21 days while the third was exposed to sunlight for a period of 21 days and after which some physicochemical tests including conductivity, sulphate, calcium, chlorine, nitrite, nitrate, pH, alkalinity, temperature, salinity, total dissolved solids; were carried out on the samples. The physicochemical characteristics of the collected samples varied depending on the atmospheric condition under which they were stored. Nevertheless, when compared with the control, the rainwater samples had more sulfate, lead, nitrite and nitrate content. This could be related to the industrial activities going on in these areas. The samples exposed to sunlight had improved and desirable physicochemical characteristics compared with the pre-exposed samples and those kept in the darkroom. These results indicate that exposing rainwater to sunlight rather than storing them in a darkroom can help improve its physicochemical qualities, thereby making it more acceptable for drinking and for domestic purpose. The government and non-governmental organizations should help provide portable water for communities that lack such, so that they do not get exposed to water pollution outcome and its risk associated consequences.

Introduction

Water is a basic requirement for life as most persons (especially adults) can stay without food for some days but not without water. The human blood plasma is made up of 92% water, just 8% of blood plasma proteins and minute amounts of other materials. The human body is made up of about 70% water [1]. At least 2 litres of drinking water which should be free from biological, chemical and physical impurities is needed by humans daily [2,3]. The scarcity of water is thus an issue and where its supply is low in most communities, they are forced to depend on sources of water that are easily accessible. The ease with which rainwater can be obtained has caused many especially in developing and underdeveloped nations to depend fully or partly on rainwater. More so, due to the decrease in the availability of potable water, there has been an increase in dependence on rainwater [4]. Often times, it is harvested from the roofs of buildings into plastic buckets, clay pots, drums made with cement or any container suitable for holding water and probably stored for a while before it is used. The impact of climatic change on the physicochemical quality of rainwater is of concern as rainwater has been an alternative and major source of water supply especially in areas where there is either scarcity or no supply of potable water. Within the interference of pollutants especially from the atmosphere, water may be regarded as pure. Harvesting of rainwater is a cheap and easy to acquire method that entails collection of the water mainly from roof catchments, storing and using it for domestic, environmental and agricultural purposes [5]. In most areas, the quantity rather than quality of the rainwater is taken into consideration [6]. Some persons introduce chlorine to the fetched water to purify it while others just store them in drums within a room and others to expose them to sunlight in large drums. Although, these

processes help in sedimentation of solid particles in the water to the bottom of the drums or containers, little is known on whether the water is purified through this process. The interference of some elements with rainwater in the atmosphere and the environment in which they are stored leads to altered chemistry of the water. Normally, the water we drink contains calcium, magnesium, sulphate, nitrate, manganese, iron and gases such as oxygen, carbon dioxide and nitrogen [7]. Some of these elements are beneficial at certain levels (e.g., chloride and fluoride) while some such as the heavy metals (e.g., lead, nickel, and arsenic) are toxic. In some cases where the fluoride content of rainwater used for drinking purpose is low, consumers add a fluoride supplement to prevent tooth decay [8]. Most of these atmospheric pollutants are present as a result of industrial activities such as fertilizer production and application, flaring of gases, incomplete combustion of fuels and others carried out in these areas. These pollutants are in form of sulfates, polycyclic aromatic hydrocarbons, dioxins and nitrates at different quantities [9]. Gaseous pollutants move up the atmosphere, displace and affect air quality; these condense in the cloud and then fall as rain [10].

Chemicals such as cobalt, iron, copper, phosphate, ammonia, nitrite, nitrate, zinc, chromium, aluminum, manganese and magnesium when present in water in excess of the tolerable amount, have been found to be harmful to human health. Increased dissolved oxygen causes an increase in temperature and thus increased microbial activity while an increase in pH makes the water have a bitter taste and makes it corrosive [11]. The presence of these physicochemical parameters at certain level affects the pH, salinity, alkalinity, colour, dissolved oxygen, hardness and electrical conductivity thus, making the water quality lower than the WHO approved tolerable limits [12].

In a study carried out by Igwo-Ezikpe and Awodele [13] in an industrial location in Lagos State in Nigeria, analyses of the physicochemical qualities of rainwater within the area indicated that the water was contaminated and as such not safe for human consumption. This study was thus aimed at determining the effect of altered atmospheric exposure to the physicochemical qualities of rainwater in comparison to the unexposed rainwater.

Methodology

Study area

Rivers State is located in the oil-rich Niger Delta Region of Nigeria and is made up of 23 local government areas. Trans-Amadi and Rumuolumeni are located in Obio/Akpor local government area of rivers state while Diobu is located in Port Harcourt city local government area of rivers state. All three locations are however located within the Port Harcourt metropolis. Port Harcourt's population is about 1,382,592 with a population density of $2,700/km^2$. In recent and past years, this city has recorded increased growth in development, urbanization and population that is not commensurate with

the quality and quantity of social infrastructure on ground. It is home to several firms including petroleum and cement industries. The area usually experiences heavy rains with a very short dry season [14] Diobu is a densely populated area with a large market, a motor park with other commercial activities going on. Banks, schools and residential homes are also located within the area. Rumuolumeni is also a populated area with the presence of companies, petrol stations, a jetty, schools and a market. Trans-Amadi has a large presence of different industries including a brewery thus making it a very busy area and increasing the circulation of particulate matter. In all of these areas, there is a huge population of cars and heavy-duty vehicles that emit carbon monoxide, thus serving as an additional source of pollution.

Sample collection and analysis

The rainwater was allowed to fall for about three minutes and then collected in duplicates directly as the rain fell using pre-sterilized bottles and were collected within the month of April. After collection, the bottles were immediately corked and transported to the laboratory aseptically for analyses. The temperature and pH of the samples were measured mercury-in-glass thermometer and Horiba n-10 water checker at the site of collection respectively.

Physicochemical analysis

Determination of the physicochemical parameters was explored according to the method by Akubuenyi et al. [12] and the results were compared with WHO standards to keep track of its variation. The turbidity, total dissolved solids, nitrate, nitrite, chlorine, electrical conductivity, sulphate, total hardness, total alkalinity, dissolved oxygen, calcium, magnesium and lead were determined according to standard methods as referenced above.

Statistical analysis

Results obtained from this study were analyzed using standard statistical tools including mean, standard deviation and T-test. Presentation of results was done using tables as shown in the results section.

Results

Physicochemical analysis of the rainwater samples obtained from Trans-Amadi, Rumuolumeni and Diobu which were kept at two different atmospheric conditions showed that those exposed to sunlight had changed and desirable physiochemical qualities compared with those kept in the darkroom and the pre-exposed samples. The mean turbidity of the pre-exposed samples reduced from 9 to 6 when the sample were kept in a darkroom and then to 3 when they were exposed to sunlight. The pre-exposed sample of sample B (Trans-Amadi) had the lowest pH (4.75), pre-exposed sample of sample C (Rumuolumeni) had a pH of 5.07 while that of sample A (Diobu) had a pH of 6.04. The sulphate content of the samples reduced from a mean value of 2.1 for the pre-exposed samples

to 1.8 for the darkroom samples and then 1.6 for the post-exposed samples. The mean value of the total hardness of the samples reduced from 4.3 for both the pre-exposed and the darkroom samples to 4.27 for the post-exposed samples. The mean nitrate content of the pre-exposed samples reduced from 0.06 to 0.05 for the darkroom samples and less than 0.05 for the post-exposed samples. The mean nitrite content however increased from 0.203 for the pre-exposed samples to 0.216 for the post-exposed samples, while the darkroom reduced the nitrite content to 0.174. The mean total dissolved solid of the pre-exposed samples was reduced from 8 to 5.3 when they were exposed to sunlight and to 6.7 when they were kept in a darkroom (Tables 1-3).

Table 1 Physicochemical analysis of pre-exposed samples.

Parameters	Sample A	Sample B	Sample C	Mean	Mean ± SD	P-value	Control	WHO Limits
Turbidity (NTU)	12	8	6	9	9 ± 3.05	0.039	1	5
Electrical conductivity (µs)	11	15	12	12.7	12.7 ± 2.08	0.009	10	500
Total dissolved solids (mg/l)	8	9	7	8	8.0 ± 1.00	0.005	7	250-500
Salinity	0	0	0	0	0	-	0	4
pH	6.04	4.75	5.07	5.29	5.29 ± 0.67	0.005	6.88	6.5-8.5
Sulfate (mg/l)	1.7	2.3	2.2	2.1	2.10 ± 0.32	0.008	<1.0	10.15
Nitrate (mg/l)	0.05	0.07	0.07	0.06	0.06 ± 0.01	0.011	0.11	50
Nitrite (mg/l)	0.005	0.58	0.023	0.203	0.203 ± 0.33	-	ND	0.2
Chloride (mg/l)	1	1	1	1	1.0 ± 0.0	-	2	200
Total hardness (mg/l)	3.8	4.9	4.1	4.3	4.3 ± 0.57	0.006	3.8	500
Total alkalinity (mg/l)	12	16	13	13.7	13.7 ± 2.08	0.008	60	200
Dissolved oxygen (mg/l)	6.5	8	6.8	7.1	7.1 ± 0.79	0.004	5.7	14
Calcium (mg/l)	0.8	1.1	0.82	0.9	0.9 ± 0.17	0.008	0.8	50
Magnesium (mg/l)	0.5	0.8	0.6	0.6	0.6 ± 0.15	0.019	0.5	30
Lead (mg/l)	0.001	0.0016	0.0012	0.0013	0.0013 ± 0.003	-	ND	ND
Temperature (°C)	27.6	27.6	27.6	27.6	27.6 ± 0.0	-	27.6	20-30

ND: Not detected; NTU: Nephelometric Turbidity Unit; SD: Standard Deviation; WHO: World Health Organization

Table 2 Physicochemical analysis of post-exposed samples.

Parameter	Sample A	Sample B	Sample C	Mean	Mean ± SD	P-value	Control	WHO Limits
Turbidity (NTU)	3	2	4	3	3.0 ± 1.00	0.035	0	5
Total dissolved solids (mg/l)	4	4	3	3.7	3.7 ± 0.58	0.008	8.8	500
Electrical conductivity (µs)	5	6	5	5.3	5.3 ± 0.58	0.004	125	500
Salinity	0	0	0	0	0	-	0	4
pH	7.1	5.42	6.23	6.25	6.25 ± 0.84	0.006	6.98	6.5-8.5
Sulfate (mg/l)	<1.0	1.95	1.2	1.6	1.6 ± 0.53		<1.0	250
Nitrate (mg/l)	<0.05	<0.05	<0.05	<0.05	0	-	0.05	50
Nitrite (mg/l)	0.006	0.61	0.031	0.216	0.22 ± 0.34		ND	0.2

Chloride (mg/l)	1	1	1	1	1.0 ± 0.0	-	4.9	200
Total hardness (mg/l)	3.8	4.8	4.2	4.27	4.27 ± 0.50	0.005	3.8	500
Total alkalinity (mg/l)	8	14	6	9.3	9.3 ± 4.16	0.06	48	200
Dissolved oxygen (mg/l)	6.5	8.3	6.5	7.1	7.1 ± 1.04	0.007	7.3	14
Calcium (mg/l)	0.8	1	0.82	0.9	0.9 ± 0.11	0.005	0.8	50
Magnesium (mg/l)	0.5	0.8	0.6	0.6	0.6 ± 0.15	0.019	0.5	30
Lead (mg/l)	0.0014	0.0021	0.001	0.0015	0.0015 ± 0.0006	-	ND	ND
Temperature (°C)	36.4	36.4	36.4	36.4	36.4 ± 0.0	-	36.4	20-30

Table 3 Physicochemical analysis of dark room samples.

Parameter	Sample A	Sample B	Sample C	Mean	Mean ± SD	P-value	Control	WHO limits
Turbidity (NTU)	8	5	5	6	6 ± 1.73	0.027	1	5
Electrical conductivity (μs)	8	11	10	9.7	9.7 ± 1.53	0.008	22	500
Total dissolved solids (mg/l)	6	8	6	6.7	6.7 ± 1.15	0.01	8.2	500
Salinity	0	0	0	0	0		0	4
pH	6.64	4.92	5.19	5.58	5.58 ± 0.93	0.009	6.9	6.5-8.5
Sulfate (mg/l)	<1.0	1.8	1.8	1.8	1.8 ± 0.0	-	<1.0	250
Nitrate (mg/l)	<0.05	0.05	0.05	0.05	0.05 ± 0.0	-	0.05	50
Nitrite (mg/l)	0.003	0.5	0.02	0.174	0.174 ± 0.28	-	BDL	0.2
Chloride (mg/l)	1	1	1	1	1.0 ± 0.0	-	2.5	200
Total hardness (mg/l)	3.8	4.9	4.1	4.3	4.3 ± 0.57	0.006	3.8	500
Total alkalinity (mg/l)	12	15	13	13.3	13.3 ± 1.53	0.004	57	200
Dissolved oxygen (mg/l)	8.1	9.8	8.7	8.9	8.9 ± 0.86	0.003	8.8	14
Calcium (mg/l)	0.8	1	0.82	0.9	0.9 ± 0.11	0.005	0.8	50
Magnesium (mg/l)	0.5	0.8	0.6	0.6	0.6 ± 0.15	0.019	0.5	30
Lead (mg/l)	0.0007	0.0014	0.0007	0.0009	0.0009 ± 0.0004	-	BDL	ND
Temperature (°C)	29	29	29	29	29.0 ± 0.0	-	29	20-30

BDL: Below Detection Limit.

Discussion

Due to the increased industrial activities going on in these areas, the physicochemical characteristics of the rainwater have been quite altered as evidenced in the results from the pre-exposed samples, making the water relatively unsafe for consumption. The rainwater in these regions could be able to pick up contaminants such as pesticides, hydrocarbons and solid particles from the atmosphere [15]. Most of the physicochemical parameters of the water samples improved when they were exposed to sunlight and a very few when they were kept in a darkroom. The post-exposed samples also had better physicochemical qualities that the pre-exposed and darkroom samples in relation to the control and WHO standards.

The high turbidity of sample A can be attributed to the increased commercial activities going on in this area. Located in this area is a large market, motor car park, banks and a dense population. The area is always busy with movement and business activities going on even at night. The turbidity of all three locations were however, statically significant at a significance level of 5%.

The pre-exposed sample of sample B (Trans-Amadi) had the lowest pH (4.75), pre-exposed sample of sample C (Rumuolumeni) had a pH of 5.07 while that of sample A (Diobu) had a pH of 6.04. This indicates that all three samples were acidic and as such not suitable for drinking according to the WHO standard [16]. The pH of sample B increased to 5.42, sample C to 6.23 and sample A to 7.10 after all the three were exposed to sunlight for a period of 21 days. Samples kept in the darkroom and observed after 21 days had little change in pH. Darkroom sample B had a pH of 4.92; sample C had a pH of 5.07 while sample A had a pH of 6.04. The low pH of sample B and C may be attributed to the level of industrial activities going on in these areas, thus emitting acidic substances into the atmosphere that interacts with rainfall. Although pH may not have a direct impact on human health, for the fact that it is less than the WHO [16] standard, it is unsafe for drinking. All the parameters tested were statistically significant at a confidence level of 5%. The contamination of these samples may be due to the presence of these contaminants in air which could probably be linked to uncontrolled unsafe industrial activities within the study location [16,17].

The low (acidic) pH of the pre-exposed samples is in agreement with that obtained by Dami et al. [10] in their study on the atmospheric water quality of rainwater from some locations in Delta State which is also in the Niger Delta region and is prone to hydrocarbon pollution due to oil exploration activities including gas flaring. The other parameters tested however differed and this could probably be as a result of variation in the amount of both particulate and gaseous pollutants emitted to the atmosphere.

There is usually variation in nitrate levels based on the location as this depends on the source of nitrate contamination to the atmosphere [18]. The ingestion of nitrates may lead to methemoglobinemia (widely known as blue baby syndrome). Respiratory tract infections and goiter development in children may also result from excess ingestion of nitrates [19,20]. Consumption of water containing nitrates may dispose one to bladder and ovarian cancer and at the chromosomal level insulin-dependent diabetes mellitus and genotoxic effects [21]. Thus, the public health implication of these circumstance is huge, hence should be controlled and prevented at all time.

The lead content however, increased in the samples that were exposed to sunlight and those kept in the darkroom for period 21 days. This amount of lead may also be attributed to the burning of fuels by the power generating plants located in these areas and vehicles moving within the area. Lead naturally occurs in soil and water in very minute quantities and it is also a normal component of the earth's crust [22]; however, water is able to pick up lead contamination from car exhausts, paints and industrial wastes, thus this is potentially possible where there is visible lack of proper disposal of industrial waste [23]. Exposure to lead has accounted for 9.8% of world burden of idiopathic intellectual disability, 5% of the global burden of stroke and 4% of the world burden of ischemic heart disease [24]. Other effects of exposure of high doses of Lead include damage to the digestive, reproductive, nervous, immunological and skeletal systems [25-27]. Bellinger et al. [28] noted that even at little concentrations of lead may cause delay in development of fetus, low birth weight and miscarriage of the fetus. According to WHO [24], no amount of lead is considered safe for consumption, as such rainwater containing Lead should not be consumed.

Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) are two cations that are indispensable for different processes in the both human and animal bodies and as such they are needed in water in sufficient quantity; although, at increased concentrations they make water unfit for living organisms [29]. The low magnesium content of the rainwater samples compared with that of calcium can be traced to the abundance of calcium in the earth's crust when compared with magnesium. The bones, teeth and soft tissues of the human require calcium as a structural component; it is also needed for majority of the metabolic processes carried out in the body [30]. In general, the ingestion of calcium in excess for a short period of time has no adverse effect but when it is consumed in excess may lead to urinary tract calculi, by percalcemia (increased level of calcium in blood), calcification in soft tissues such as arterial walls, kidneys and the suppression of bone remodeling [31].

Conclusion and Recommendation

Water is essential for life; thus, its provision should be given priority as man can survive for a while without food but not without water. Rainwater among other water sources is however, the most easily accessible and as such safety measures should be carried out to ensure it is safe for consumption. Generally, the atmosphere gets polluted with both gaseous and particulate matter that diffuses into the cloud thus making rainwater which is supposed to be potable, unsafe for consumption. It is therefore important that rainwater is not consumed without being purified. Although exposure of rainwater to sunlight can reduce its turbidity, total dissolved solids, total alkalinity, pH, electrical conductivity, sulphate, nitrate and nitrite content to standard levels so that they can be used as potable water, however it also increases its Lead content thereby making it unsafe for drinking and most domestic purposes. The use of fuels and paints containing little or no lead should be encouraged in order to reduce the circulation of lead in the environment. This study however, shows that although exposure of rainwater to high temperature or sunlight can improve its quality, adequate treatment of rainwater needs to be done before it is consumed to prevent water-related diseases. Furthermore, the researchers strongly suggest that more rigorous study could be directed in this focus of research so as to underpin more robust means of improving water quality, especially, rainwater quality since it is the easier to access compared with the other sources of water especially in our local communities with poor visible access to potable water provision and lack of basic water infrastructure.

Conflict of Interest

None was reported among authors.

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