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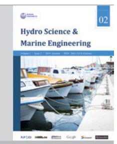

ARTICLE

Rain Water Characterization at Urban and Rural (North B) Unguja

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ABSTRACT

Aim of the study was to assess the physicochemical characteristics of rainwater at urban and rural (north B) Unguja. Twenty four (24) rainwater samples were analyzed for pH, electrical conductivity (EC) and total dissolved solids (TDS) and cations: calcium (Ca^{2+}), copper (Cu^{2+}), iron (Fe^{2+}), chromium (Cr VI) , and anions: fluoride (F^-), nitrite and sulfate (SO_4^{2-}). The investigated physicochemical parameters in the rainwater samples were within the permissible limits of the World Health Organization (WHO) drinking water quality guidelines. The ranges of concentration for the physical parameters analyzed were; pH: (5.8 – 7.7), EC: (5.08 – 35.6 µS/cm), TDS: (1.68 – 20.16 mg/L, Ca: (0.163 – 24.331 mg/L), Cr: (VI) : (BDL – 0.029 mg/L), Cu: (BDL - 0.085 mg/L); Fe: (BDL – 0.068), anions were SO_4^{2-} : (BDL – 5.00 mg/L) and F- : (BDL – 0.5 mg/L). Nevertheless, there was no significant difference for the measured parameters between urban and rural areas. This is a good indication that the air quality in Zanzibar is remarkably not polluted with respect to the parameters studied.

1. Introduction

Water is among the primary needs of life, playing important roles including human consumption, industrial processing, irrigation and domestic waste water management [1]. The human existence and physiology depend much on availability of good quality water [2]. Safe drinking water is more important for human life, however much of the world's population does not have access to safe drinking water [3].

The growing of human population and other living organisms threaten the water resources due to demanding the quality water for domestic and economic activities purposes [4]. Decision-makers faces significant challenges on the issues of supplying adequate water to the rapidly growing population especially in most urban area, where by the societal needs and equity on water access is required.. However the water quality changes during processes like harvesting, storage and house hold use [5].

Rainwater resources and others like river, sea and ground water are on a great serious threat from over uses or pollution due to anthropogenic activities or sources like combustion of fuels for energy generation, heating, transport and industrial needs, previously polluted and waste disposal sites, wind blow soils from arid and agricultural regions [6,7].

Acid rain is referred as any rain fall containing excessive amount of dissolved acid gases like SO_2, NO_2 and CO_2 and particulate matter in the atmosphere, rain water becomes acidic if the pH is less than 5.5 when it falls to the surface [8].

Rainwater is a free source that can be obtained naturally and considered to be the purest form of water which formed through natural distillation. This water contains dissolved

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gases such as nitrogen dioxide, ammonia, sulphur dioxide, aerosol or particulate matter from atmosphere [9,10,11]. Rainwater acts as a collector which is used to detect and control the concentration of gaseous and particulate matter that includes the trace metal in the atmosphere [12].

Remarkably, water reserve has been found to be in short supply globally; the water shortage has sent man on the lookout for new alternative water resources of rainwater harvesting that may take the role of intake of number of nutritional and toxic trace elements in man. [13]. Therefore, this study aims at determining the concentration of cations (Ca^{2+}, Cu^{2+}, Fe^{2+}, Zn^{2+}, Cr (VI) and anions (F^-, NO_2^-, SO_4^{2-}) at selected areas of Urban and rural (north B) in Zanzibar Island. Other parameters such as EC, pH and TDS were also determined. Moreover, comparison of the level of these ions was made between Urban and Rural areas. Nevertheless, the measured parameters in rainwater were compared to WHO guidelines to ascertain its suitability for human consumptions.

2. Materials and Method

2.1 Study Area

The study was conducted at urban west region and North B District of Unguja Island in Zanzibar. Rainwater samples were collected at fourteen (14) locations in urban west region and ten (10) locations in rural North B district. The geographical positioning system GPS was used to locate the sampling station (Appendix 1 and Figure 1).

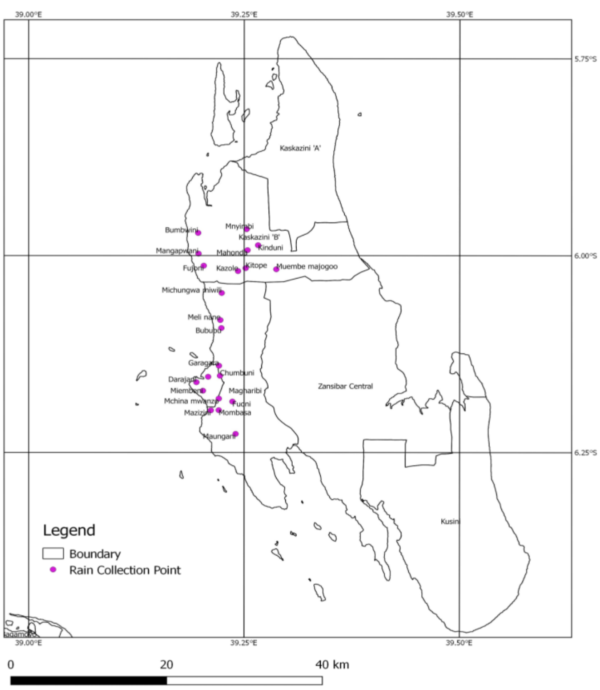

Figure 1. Rain water collection points

2.2 Samples Collection and Storage

On November and December 2016, twenty four rainwater samples were collected from different sites of urban and rural north B areas of Unguja Zanzibar. Immediately after collection, the pH, TDS and conductivity of rainwater samples were measured using HI19812 pH/EC/TDS METER. The handling, storage and preparation of the samples were done in accordance with the standard EPA method 2007.

2.3 Methodology

The analytical and laboratory works by using appropriate standard method were carried out in the Chief Government Chemist Laboratory Agency (CGCLA) Zanzibar and University of Dar- es - salam (UDSM) Tanzania. Table 1 depicts summary of the equipments/ instrument used and parameters analyzed.

Table 1. Parameters Analyzed and the Instrument Used

Parameters	Equipments/Instrument	Test methods
Electrical conductivity (EC), Total dissolved solid (TDS) and pH	HI 19812 pH/EC/TDS METER	Insitu measurement
Sulfate (SO_4^{2-})	UV-1800PC Spectrophotometer	Turbid metric method
Chromium (Cr (VI), copper Cu^{2+} and Fluoride (F^-)	HI 83099 COD and Multiparameter photometer	ASTM D1687-92, DiphenylcarbohydrazideEPA and SPADNS method
Calcium (Ca^{2+}), Iron (Fe^{2+})	Atomic Absorption Spectrophotometry (AAS)	EPA method 2007

2.4 Statistical Analyses

SPSS version 20 was used for the data analysis. The descriptive statistics and Pearson's correlation significant used to examine correlation between selected parameters in water samples is summarized in Table 2.

Table 2. Summary of the Descriptive Statistics of the Analyzed Parameters in Rainwater

Parameters		Mean	Minimum	Maximum	P value	WHO GUIDLINES
pH	1	6.864	6.4	7.7	0.001	6.5 – 8.0
	2	6.290	5.8	7.1		
EC	1	13.848	5.10	33.00	0.902	1500
	2	14.288	5.08	35.60		
TDS	1	7.545	2.415	16.11	0.863	500
	2	7.912	1.68	20.16		
F-	1	0.1057	BDL	0.5	0.56	1.5
	2	0.750	BDL	0.25		

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SO_4^{2-}	1	1.507	BDL	4.5	0.926	400
	2	1.570	BDL	5.0		
Fe^{2+}	1	0.0127	BDL	0.0680	0.132	0.3
	2	0.0012	BDL	0.0037		
Cu^{2+}	1	0.035	BDL	0.18	0.217	2.0
	2	0.021	BDL	0.052		
Cr VI	1	0.00057	BDL	0.003	0.034	0.05
	2	0.0097	BDL	0.040		
Ca^{2+}	1	3.529	0.49	24.331	0.854	75
	2	3.136	0.163	8.410		

Note: 1 - Represent urban areas 2 - Represent rural areas.

3. Results and Discussion

The comparison of the levels of the analyzed parameters between the present study with other studies is highlighted in Table 3.

Table 3. Parameters comparison between the present study with other studies

Parameters	Present study (Parameters Range)	Other Studies (Parameters Range)
PH	5.8 – 7.7	6.22 – 6.92 [14], 6.62 [15].
EC	5.08 – 35.6	14.39 – 43.18 [14], 13.45 – 19.04 [15].
TDS	1.68 – 20.16	7.0 and 25.3 [16], 0.05 – 51 [17]
F^-	BDL – 0.5	0.54 -0.86 [15], 0.07 - 0.48 [18]
SO_4^{2-}	BDL – 5.0	0.057 – 0.396 [19], 2.00-19.00 [20], 3.22 – 7.83 [21].
Fe^{2+}	BDL – 0.068	0.15 – 0.79 [15], 0.6 – 2.2 [14], 17 - 82 [22]
Cu^{2+}	BDL – 0.085	BDL – 0.0009 [14], 0.0028 - 0.0139 [22], 0.0399 - 0.1506 [23].
Cr (VI)	BDL – 0.029	0.00047 – 0.0017 [24]
Ca^{2+}	0.168 – 24.331	0.6 – 0.8003 [14].

Note: All parameters expressed in mg/L except EC (μS/cm), pH (no unit).

3.1 pH

In this study, It was observed that the pH values in rainwater samples varied from 5.8 to 7.7 (Table 3, Appendix 2 and Figure 2) with a mean pH of 6.86 for urban zone, and pH 6.29 for rural areas. There was significant difference for pH (0.001, $P<0.05$) between the urban and rural sites. The lowest pH was recorded at Michungwa miwili, and highest at Darajani. The pH range was slightly higher as compared with similar study in Unguja, Zanzibar (Table 3). Nevertheless, the pH of the present study corresponds to other study whose mean pH value was 6.62 (Table 3). The lower pH value obtained from michungwa miwili (north B) Unguja possibly due to spatial and temporal variation in the atmospheric chemical composition. Moreover, anthropogenic sources, such as agriculture could be a sound reason.

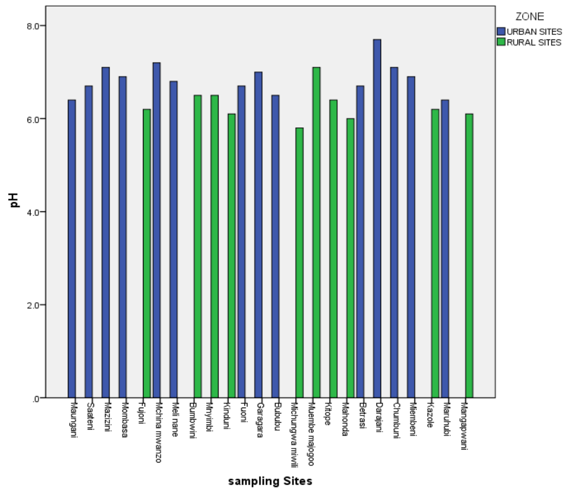

Figure 2. pH of rainwater samples

3.2 Electrical Conductivity (EC)

The lowest conductivity value (5.08 µS/cm) recorded was at Mchina mwanzo, and highest (35.6 µS/cm) at Bumbwini (Figure 3), this could be due to accumulation of various particles of dust, soil, and airborne aerosols that dissolve prior to deposition [25]. Notably, there was no significant difference (0.902, $P<0.05$) for EC between the urban and rural sites. The range of EC is lower as compared with similar study conducted in urban west region of Zanzibar Island (Table 3). Low level of electrical conductivity (EC) in rainwater is an indication that the atmosphere has not been highly scavenged by ions containing aerosols. This finding is consistent with rainwater conductivity level from Tamale metropolis (Table 3).

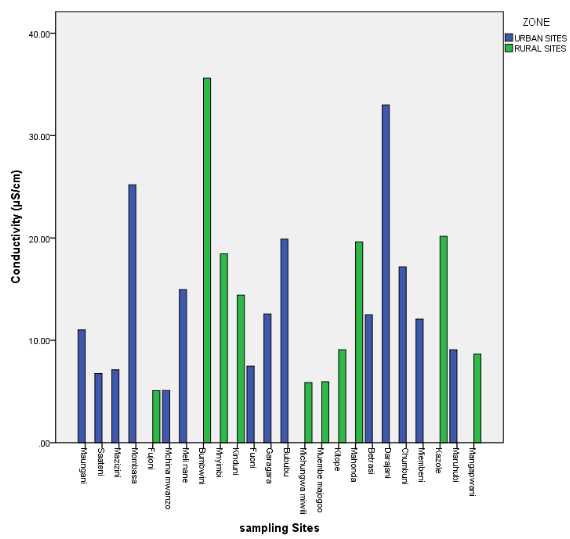

Figure 3. Electrical Conductivity of rainwater samples

3.3 Total Dissolving Solids (TDS)

TDS values varied from 1.68 to 20.16 mg/L (Table 2, Appendix 2 and Figure 4) with mean of 7.545 and 7.912 ppm at urban sites and at rural sites respectively. There was no significant difference (0.863, $P<0.05$) of TDS between the urban and rural sites. The lowest value obtained for TDS was at Muembe majogoo and highest found at Kazole, this high value reported could be due to the suspended of particulate matter in atmosphere. The finding is consistent with the studies reported at Kotei Ghana and Tamale municipality (Table 3), but all values were within the WHO safe limits (500 mg/L).

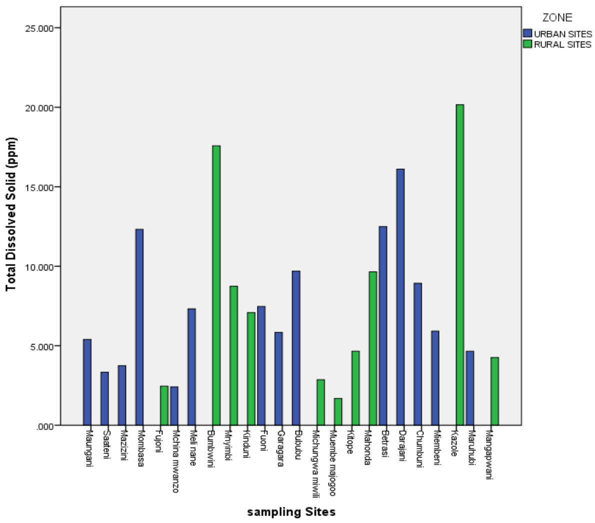

Figure 4. TDS in rainwater samples

3.4 Fluoride

The concentration of fluoride was found to range from BDL to 0.5 mg/L with a mean of 0.1057 mg/L at urban sites and 0.750 mg/L at rural sites (Table 2, Appendix 2 and Figure 5). All samples concentrations were within WHO limits (1.5 mg/L) and basically there was no significant difference (0.56, $P<0.05$) of fluoride between the urban and rural sites. The lowest concentrations of fluoride were detected at Mangapwani, Maruhubi and Fujoni while the highest was detected at Mazizini. This may be due to the occurrence of fluorine in atmospheric air. Also burning of plastic use fluoride-containing substances could pollute the environment with fluoride gas, fumes. or smoke contribute to the environmental fluoride pollution [18], which inturns can contaminate rain water. The fluoride of the present study corresponds to other studies conducted at Ayanfuri, Ghana and Bangladesh (Table 3).

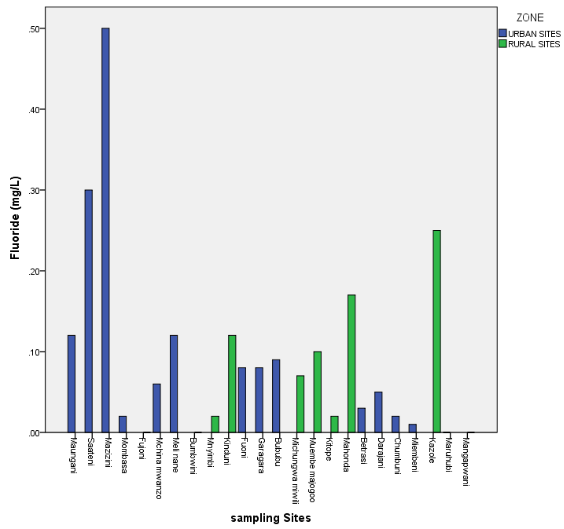

Figure 5. Fluoride level in rainwater samples

3.5 Sulfate

As depicted from Figure 6, Appendix 2 and table 2, the SO_4^{2-} concentration varied from BDL (At Mangapwani, maruhubi Kazole, Miembeni, Fuoni and Chumbuni) to 5 mg/L (at Bumbwini) with a mean of 1.507 mg/L at urban sites and 1.57 mg/L at rural sites. The study didn't show any significant difference (0.920, $P<0.05$) of sulfate concentration between urban and rural sites selected. This could be anthropogenically attributed via burning of sugarcane, soil dust or industrial emission at Mahonda sugar factory. The result collected was below the WHO recommended level of 400mg/L. This study to some extent corresponds to other similar studies. Conducted at different areas (Table 3).

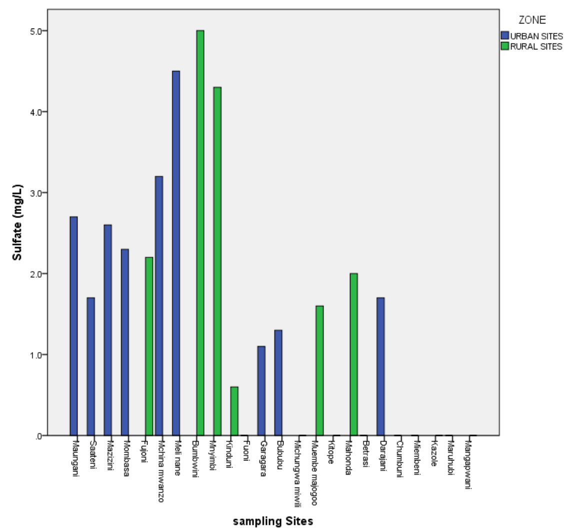

Figure 6. Sulfate level in rainwater samples

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3.6 Iron

Iron concentrations ranged from BDL to 0.068 mg/L with a mean of 0.0127 mg/L at urban sites and 0.0012 mg/L at rural sites. All recorded concentrations were below the WHO limit of 0.3 mg/L. The concentrations of iron were below detection limit for over sixty percent of sampling sites (Table 2, Appendix 2 and Figure 7). Highest concentration of iron was measured at Mazizini and Maungani this could be contributed from agricultural practices. There was no significant difference (0.132 P<0.05) of Iron between the urban and rural sites. The iron concentration range of this study was lower as compared with similar studies conducted on other areas (Table 3).

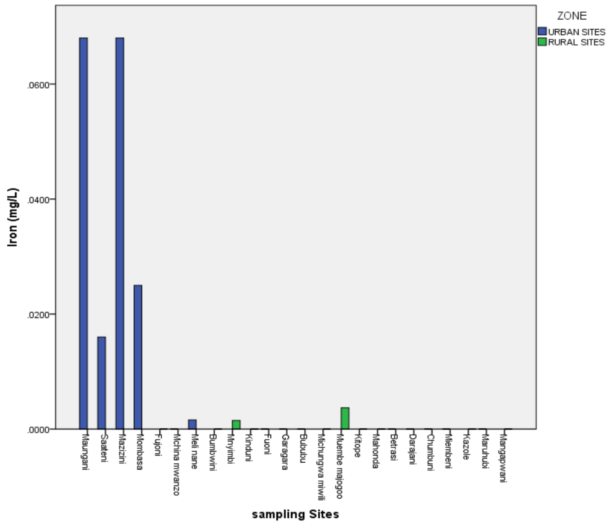

Figure 7. Iron level in rainwater samples preferred

3.7 Copper

The concentration of copper ranges in rainwater samples from BDL – 0.18 mg/L and BDL – 0.052 mg/L at urban and rural areas respectively (Table 2, Appendix 2 and Figure 8). They were below the WHO guidelines (2.0 mg/L). The concentration of copper between the urban and rural sites didn't show any significant difference (0.217, P<0.05), where the highest value of 0.18 mg/L was recorded at Saateni (sample number 2), and the lowest concentration recorded bellow the detection limit at Bumbwini, Kazole, and Mangapwani (samples number 8, 22 and 24 respectively). Basically, the value of copper reported in this study is comparable with other studies (Table 3).

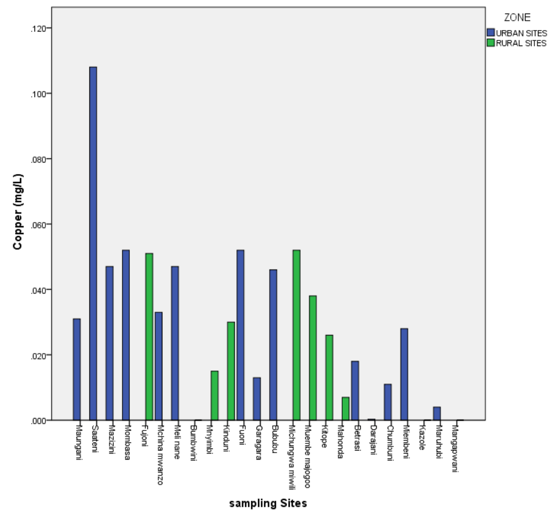

Figure 8. Copper level in rain water samples

3.8 Chromium

The Cr (VI) in some rainwater samples was below the detection limit, and maximum concentration was 0.029 mg/L (Table 2, Appendix 2 Figure 9), which was lower than the WHO permissible limit (0.05 mg/L). A comparison of results of chromium in rainwater samples affirmed that there was a significant difference (0.034, P<0.05) between the urban and rural sites. The study conducted at peri-urban region of Kleinmond and Western Cape (Table 3) show good correspondence with the chromium data of this study. The high level of chromium at rural sites could be attributed from industrial activities at mahonda sugar factory.

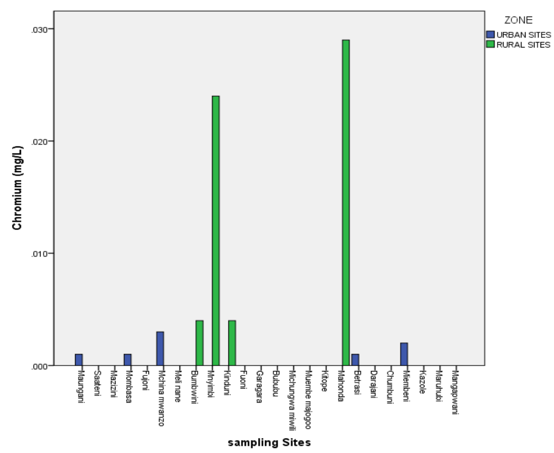

Figure 9. Chromium level in rain water samples

3.9 Calcium

The mean concentration of calcium in rainwater samples were 3.529 mg/L and 3.136 mg/L at urban and rural areas

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respectively (Table 2, Appendix 2 and Figure10. There was no significant difference (0.854, $P<0.05$) of calcium between the urban and rural sites. The lowest value of calcium (0.163 mg/L) was found in Fujoni. and the highest concentration of calcium (24.331 mg/L) was obtained in sample collected from Maruhubi, this could be attributed with the building materials of five star hotel, which is located nearby sample collection point. All data of calcium observed were below the WHO limit (75 mg/L), (Table 3).

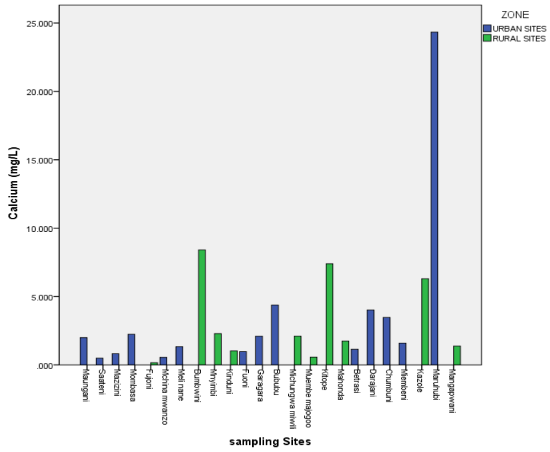

Figure 10. Calcium level in rainwater samples

4. Conclusion

In this study there was no significance difference of the data for almost all parameters analyzed between urban and rural sampled sites except for the pH which observed to be low at rural sites compared to urban site; this could be contributed with sugar factory operations including sugarcane burning. The investigated physico-chemical parameters (pH, EC and TDS) and (Ca^{2+}, Cu^{2+}, Fe^{2+}, Cr VI), F^- and SO_4^{2-}) in the rainwater samples from urban and rural (north B) in Zanzibar Island were found below the guidelines for drinking waters given by the World Health Organization (WHO), making the rainwater suitable for drinking and recreational purposes. The best quality of rainwater selected points can be easy used as primary information for the assessment of air pollution.

Appendix

Appendix 1. Sampling Stations with GPS

S.No	Sampling Sites	Station ID	Coordinate S	Coordinate E
1.	Maungani	S01	6˚13.582’	39˚14.404’
2.	Saateni	S02	6˚09.232’	39˚12.490’
3.	Mazizini	S03	6˚11.789’	39˚12.676’
4.	Mombasa	S04	6˚11.774’	39˚13.227’
5.	Fujoni	S05	6˚00.770’	39˚12.183’
6.	Mchina mwanzo	S06	6˚10.893’	39˚13.234’
7.	Meli nane	S07	6˚04.911’	39˚13.336’
8.	Bumbwini	S08	5˚58.273’	39˚11.791’
9.	Mnyimbi	S09	5˚57.987'	39˚15.165'
10.	Kinduni	S10	5˚59.210'	39˚15.964'
11.	Fuoni	S11	6˚11.119’	39˚14.181’
12.	Garagara	S12	6˚08.391’	39˚13.243’
13.	Bububu	S13	6˚05.520’	39˚13.409’
14.	Michungwa miwili	S14	6˚02.849’	39˚13.433’
15.	Muembe majogoo	S15	6˚01.042'	39˚17.234'
16.	Kitope	S16	6˚00.956'	39˚15.101'
17.	Mahonda	S17	5˚59.587'	39˚15.230'
18.	Betrasi	S18	6˚07. 043’	39˚12.700’
19.	Darajani	S19	6˚09.648’	39˚11.674’
20.	Chumbuni	S20	6˚09.155’	39˚13.316’
21.	Miembeni	S21	6˚10.294’	39˚12.127’
22.	Kazole	S22	6˚01.182’	39˚14.568’
23.	Maruhubi	S23	5˚57.987'	39˚15.165'
24.	Mangapwani	S24	5˚59.852’	39˚11.818’

Appendix 2 (A). Levels of the analyzed parameter in rainwater samples (cations, anions, TDS, in mg/L, and EC in µS/cm)

sampling Sites	SO_4^{2-}	Cu^{2+}	Cr (VI)	Fe^{2+}	ZONE
1	2.7	0.031	0.001	0.068	1
2	1.7	0.108	BDL	0.016	1
3	2.6	0.047	BDL	0.068	1
4	2.3	0.052	0.001	0.025	1
5	2.2	0.051	BDL	BDL	2
6	3.2	0.033	0.003	BDL	1
7	4.5	0.047	BDL	0.0016	1
8	5	BDL	0.004	BDL	2
9	4.3	0.015	0.024	0.0015	2
10	0.6	0.03	0.004	BDL	2
11	BDL	0.052	BDL	BDL	1
12	1.1	0.013	BDL	BDL	1
13	1.3	0.046	BDL	BDL	1
14	BDL	0.052	BDL	BDL	2
15	1.6	0.038	BDL	0.0037	2
16	BDL	0.026	BDL	BDL	2
17	2	0.007	0.029	BDL	2
18	BDL	0.018	0.001	BDL	1
19	1.7	0.0003	BDL	BDL	1
20	BDL	0.011	BDL	BDL	1
21	BDL	0.028	0.002	BDL	1

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22	BDL	BDL	BDL	BDL	2
23	BDL	0.004	BDL	BDL	1
24	BDL	BDL	BDL	BDL	2

Appendix 2 (B). Levels of the analyzed parameter in rainwater samples (cations, anions, TDS, in mg/L, and EC in μS/cm)

sampling Sites	F^-	Ca^{2+}	pH	EC	TDS	ZONE
1	0.12	1.99	6.4	11.02	5.398	1
2	0.3	0.49	6.7	6.76	3.333	1
3	0.5	0.82	7.1	7.12	3.745	1
4	0.02	2.24	6.9	25.19	12.32	1
5	BDL	0.163	6.2	5.08	2.46	2
6	0.06	0.547	7.2	5.1	2.415	1
7	0.12	1.33	6.8	14.95	7.322	1
8	BDL	8.41	6.5	35.6	17.57	2
9	0.02	2.29	6.5	18.45	8.739	2
10	0.12	1.022	6.1	14.42	7.085	2
11	0.08	0.973	6.7	7.47	7.47	1
12	0.08	2.098	7	12.57	5.838	1
13	0.09	4.38	6.5	19.88	9.69	1
14	0.07	2.1	5.8	5.87	2.865	2
15	0.1	0.569	7.1	5.96	1.68	2
16	0.02	7.4	6.4	9.08	4.652	2
17	0.17	1.74	6	19.61	9.65	2
18	0.03	1.139	6.7	12.49	12.49	1
19	0.05	4.014	7.7	33	16.11	1
20	0.02	3.47	7.1	17.18	8.932	1
21	0.01	1.59	6.9	12.07	5.918	1
22	0.25	6.3	6.2	20.16	20.16	2
23	BDL	24.331	6.4	9.08	4.652	1
24	BDL	1.374	6.1	8.65	4.259	2

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