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The Status of Domestic Water from Six Selected Areas of Coastal Guyana

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ABSTRACT

The domestic water from six selected areas of coastal Guyana, Corriverton, Cummings Lodge, Non-Pariel, Wismar, Georgetown and Vreedenhoop were tested for the presence of selected metal ions such as Cd, Al, Fe, Pb, Cu and Zn in addition to its physical parameters of turbidity, salinity, total dissolved solids, TDS, temperature, Electrical conductivity, EC and pH. It's necessary that residents in these areas become aware of the concentration of these selected ions so as to protect their lives. The results indicate that the domestic water from Georgetown showed the highest value of 0.02 ± 0.00 mg/L for Cd whereas there was no detection for Non-Pariel and Wismar domestic water. Georgetown domestic water also registered the highest for Al (0.2 ± 0.27 mg/L). Fe recorded its highest value of 2.99 ± 0.01 mg/L for Non-Pariel domestic water, whereas there was no detection of lead in all the water with the exception of Corriverton domestic water which showed a value of 0.48 ± 0.4 mg/L. Cu and Zn registered its highest value for Corriverton domestic water with values of 0.02 ± 0.0 mg/L and 0.07 ± 0.02 mg/L respectively. These values, with the exception of Al, Cu and Zn are all higher than the WHO standards for drinking water. The WHO standards for the presence of Cd, Al, Fe, Pb, Cu and Zn in domestic water is 0.005 mg/L, 0.2 mg/L, 0.3 mg/L 0.05 mg/L, 2.0 mg/L and 5.0 mg/L respectively. The pH of the domestic water range from 5.66 to 7.2, whereas the salinity ranges from 28 ppm to 318 ppm. The latter was observed for Corriverton domestic water. TDS registered its highest value of 461 mg/L for Corriverton domestic water, whereas the lowest value of 42±0.00 mg/L was registered for Vreedenhoop water. Where the values are higher (Cd, Fe, Pd) than WHO standards, steps should be taken to rectify the situation and protect the livelihood of its citizen.

1. Introduction

Domestic water is one that is used for indoor and outdoor purposes. Indoor purposes includes uses such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, watering lawns and gardens [1-3].

Guyana, a land of many waters, is situated in Northern South America and part of Caribbean South America. It possesses a land size of approximately 197,000 square kilometers, actually about the size of Idaho. It also has water area of 18,120 km². The land comprises of three main geographical zones: the coastal plain, the white sand belt, and the interior highlands [4]. It's divided into three counties: Berbice, Demerara and Essequibo.

Guyana is facing a major environmental problem of water pollution with the primary pollutants being sewage and agricultural chemicals. The rise of agricultural production together with the growth of industries is resulting in a water crisis that can significantly affect the country in the next few years [4-6]. The sources of pollution in Guyana according to the National Development Strategy, 1996 [7,8] is shown below in Table 1.

Guyana's domestic and surface need to be monitored as development continues. However, because of the uncontrollable growth of the world's population, there has been a high demand for water which of course cannot be ignored because water is a necessity. Domestic water can be contaminated with microbes and inorganic cations/anions. To most individuals, once domestic water or drinking water looks clean, the general idea is that it is safe to drink or use for domestic purposes. However, this is not so. Safe drinking water is a vital need for human well-being, health, development, and necessity, and therefore, it is internationally recognized as fundamental human rights [9].

GWI provides water to more than 145,000 homes, offices and schools all across Guyana. It provides water also to Amerindian communities in the Hinterland. It is anticipated that the Guyana Water Incorporated, GWI provides clean, safe drinking water to the populace. The quality of water has always been a major issue in many countries, especially in developing countries [10].

The Guyana Water Incorporated (GWI) supplies potable water to over 145,000 customers in Guyana with more than 300,000,000 litres of potable water per day. GWI has water treatment plants at various places throughout Guyana, including Sophia, Better Hope, Covent Garden, Eccles, Number 56 Village, Bartica, Bel Air Park and Mon Repos. Its sources of water include ground water from wells and also surface water from areas such as Linden and at the Shelter belt (GWI website) [10].

Guyana as a whole still faces numerous water related challenges. For instance, contamination of potable water supplies, which leads to water-borne diseases like lymphatic filariasis. Water sanitation and hygiene factors were responsible for over 300 deaths in 2004, and this also accounted 3.4% of all the deaths in Guyana. It's important that the level of metal ions be below the International accepted Standard or Threshold Limit otherwise harmful effects to the populace will be realized. This paper is an investigation of the status of physical and chemical parameters: turbidity, electrical conductivity, pH, lead, chloride, etc. of domestic water in Linden and selected areas of coastal Guyana and to compare the status of the water from the different regions against the threshold limit of WHO (World Health Organization). Also, to ascertain, the level of concentration of selected cations and anions and compared with WHO and EPA standards. To the best of knowledge, such evaluation of the domestic water hasn't been done before. The World Health Organization in its guidelines for drinking water quality publication highlighted at least seventeen different and major genuses of bacteria that may be found in tap water which are capable of seriously affecting human health [11-13].

The evaluation of domestic water have been reported internationally. Several examples can be cited [9, 14-18]. The concentration of aluminium (Al) and the physicochemical parameters (pH, total dissolved solids (TDS), turbidity, and residual chlorine) in drinking water supply in selected palm oil estates in Kota Tinggi, Johor was determined [9]. Water samples were collected from the estates that use private and public water supplies. A

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total of 207 water samples were analyzed for Al concentration. The sampling points were at the water source, the treatment plant outlet (TPO), and at the nearest houses and the furthest houses from the TPO. The estates with private water supply failed to meet the NSDWQ for aluminium with mean concentration of 0.99±1.52 mg/L. However, aluminium concentrations in all public water supply estates were within the limit except for one estate. The pH for all samples complied with the NSDWQ except for the samples from the private estates for the drinking water supply with an acidic pH (5.50 ± 0.90). The private water supply showed violated turbidity value in the drinking water samples (14.2 ± 24.1 NTU). Inadequate quantity of chlorination was detected in the private water supply estates (0.09±0.30 mg/L). Private water supplies with inefficient water treatment served unsatisfactory drinking water quality to the community which may lead to major health problems.

Too much of copper in drinking water can cause flavor changes and health hazards. Under Georgia conditions, copper occurs in drinking waters due to corrosive water and the dissolution of copper plumbing. Water test results obtained by the Agricultural and Environmental Services Laboratories (AESL) indicated that about 5.6% of the household well waters submitted for analyses contained copper at concentration above EPA's primary maximum contaminant level (MCL) of 1.3 mgL^{-1}. Most of these were detected in Sand Hills and Southern Piedmont provinces. These corrosive waters were characterized by being soft (hardness < 50 ppm), slightly acidic (pH < 6.5) and less buffered owing to low alkalinity (< 50 ppm $CaCO_3$) [14].

Trace metals and some physiochemical properties in drinking water samples from the BrongAhafo region of the Republic of Ghana, where drinking water samples are not treated before it is consumed were determined [15]. Samples were taken from fifteen sampling points and analyzed for the following parameters Fe, Cu, Mn, Zn, Al, NO_3^-, NO_2^-, SO_4^2, PO_4^{2-}, and F^- using the photometer method. The data showed the variation of the investigated parameters in samples as follows: pH 5.57-7.54, conductivity (EC) 35-1216 us/cm, turbidity 3.25-72.50 NTU, PO_4^{2-}1 0.32-9.30 mg/L,F 0.32-1.05 mg/L,NO_3^- 0.09-0.99 mg/L,NO_2^- 0.006-0.114 mg/L, SO_4^{2-} 3.33-8.02 mg/L, Cu 1.19-2.75 mg/L ,Fe 0.05-0.85 mg/L, Zn 0.04-0.15 mg/L, Mn 0.003-0.011 mg/L and Al 0.05-0.15 mg/L. The concentrations were all within the permissible limits of the World Health Organization drinking water quality guidelines. Also, there were no correlations between metal concentrations in the drinking water samples.

The distribution of Arsenic and other inorganic metals in 112 samples from drinking Bangladesh's tubewell water was studied, revealing that As concentration ranged from < 0.0007 to 0.64 mg/L, with 48% of samples above the 0.01 mg/L World Health Organization drinking water guideline. Furthermore, this study reveals unsafe levels of manganese (Mn), lead (Pb), nickel (Ni), and chromium (Cr) [16].

Cu, Fe, Pb, Ni and Mn in drinking water samples was determined by atomic absorption spectrometry after preconcentration on Diaion HP-20 resin column, Soylak. Let al, (2001) [17]. The data showed the variation of the investigated parameters in water samples as follows: pH 6.90-8.13, conductivity (EC) 57.3-694.5 μsimens/cm, calcium 15-120 mg/L, magnesium 3-47 mg/L, chloride 11-77 mg/L, bicarbonate 180-701 mg/L, hardness 50-330 mg ,CaCO3 /L, total alkalinity 150-575 mg/L, Cu 0.17-1.19 μg/L, Fe 16.11-79.30 μg/L, Pb 0.18-0.99 μg/L and Mn 0.15-2.56 μg/L. Nickel concentrations in all the drinking water samples were below the detection limit. The concentrations of investigated parameters in the drinking water samples from Yozgat were within the permissible limits of the World Health Organization drinking water quality guidelines and the Water Pollution Control Regulation of the Turkish authorities.

Chemometric or multivariate methods were applied to detect the spatial variation and pollution sources of Jakara River in Kano state, Nigeria [18]. 30 water samples were collected: 23 from River Getsi and 7 surface water samples from the main channel, River Jakara. 23 water quality parameters like pH, temperature, turbidity, electrical conductivity, dissolve oxygen; BOD, Fecal Coliform, total solids, nitrates, phosphates, cobalt, iron, nickel, manganese, copper, sodium, potassium, mercury, chromium, cadmium, lead, magnesium, and calcium were analyzed. It was found that the concentration of pH is within the permissible limit set up by Nigerian standard for drinking water and World Health Organization. The average concentration of turbidity level was 51.65 $mgL^{-1}$and is above the maximum permitted level for drinking water by NSDW and WHO which is25 $mgL^{-1}$and 10 mgL^{-1}respectively. The mean value of Dissolve Oxygen obtained was 4.34 $mgL^{-1}$and 4.08 $mgL^{-1}$for BOD, the maximum allowed limit for drinking water is 5 mgL^{-1} which indicates that DO and BOD concentration values are within the NSDW and WHO guidelines. It was concluded that chemo-metric techniques provides excellent tools for water resources control and management. The coastal plain of Guyana has the highest population density which is roughly about 90%. These residents rely solely on ground and surface water supply after necessary treatment to meet their domestic needs. And this was the main reason why the coastal areas were used for this research. Linden is currently the second most populated region in Guyana.

Table 1 Sources of pollution in Guyana (National Development Strategy, 1996)

Industry	Number	Potential Pollutants
Sawmills	66	BOD, dust
Food processing	47	BOD, phosphates, solids, dust, pathogens
Detergents/soaps	9	BOD, phosphates, caustics
Metalworking/foundry	8	Heavy metals, solids
Sugar refinery	7	BOD, solids, caustics, phosphates
Chemical/pharmaceutical	6	Acids, alkaline, phosphates, solids
Distilleries/breweries	5	BOD, phosphates, thermal
Plastics	4	CFCs, solids

2. Experimental Methods

2.1 Sample Collection

The water samples were collected in 500 mL water bottles in triplicates from Cummings Lodge, Non-Pariel, Wismar, Corriverton, Georgetown and Vreedenhoop and Linden over a week period in March (Fig. 1). The samples were collected during the day and were stored in a cooler. The samples were labelled properly with student's name, sample number and name of school and the purpose of the sample, such as for final year project. The samples were later submitted the same week for analysis at GWI and GUYSUCO.

Fig. 1 The picture above shows some of the samples collected with appropriate labels

2.2 Sample Analyses via Atomic Spectroscopy [19-21]

The water samples were filtered using a pore diameter membrane filter. After filtration, the filtrates were transferred to a beaker. 5 mL of concentrated H_2SO_4 and several boiling chips were added. The contents of the beaker were brought to a slow boil and evaporated on a hot plate to the lowest volume (10 mL) to initiate precipitation. Heating was continued with the concomitant addition of HNO_3 until digestion was completed. Drying of the samples was avoided. The flask was washed with water and the contents filtered. The filtrates were then transferred to a 100 mL volumetric flask and make up to the mark. Portions of the solution were then taken for metal ion determinations by the use of Flame Atomic Spectroscopy, FAS. For each metal analysed, an appropriate standard solution of known metal concentration in the water with a matrix similar to the sample was prepared.

2.3 Data Analysis

Water analyses were carried out in triplicates for physical and chemical parameters such as turbidity, salinity, total dissolved solids, TDS, temperature, electrical conductivity, EC and pH. Metal cations: Al, Zn, Pd and anions such as Cl^-, NO_3^- SO_4^{2-} and PO_4^{3-} in domestic water were determined by Guyana Water Incorporated (GWI) and GUYSUCO. Data were analyzed statistically for mean, standard deviation, SD, variance and significance difference in mean etc., [22-24].

3. Results and Discussion

Cadmium values from the studied areas varied from 0.006 mg/L to 0.01 mg/L. Values above the threshold limit for cadmium (0.003 mg/L) were found at Corriverton, Georgetown and Vreedenhoop (Tables 2 and 3).

There was no detection for cadmium at Non-Pariel and Wismar domestic water. Abnormal values of cadmium can cause kidney damage, severe stomach pain and sometimes death to humans. Water can be contaminated with cadmium through discharge from metal refineries, corrosion of galvanized pipes and erosion of natural deposits. Aluminium values from the studied areas varied from 0.01 to 0.2 mg/L. And all the values were below the threshold limit of W.H.O, 0.2 mg/L. Iron values from the studied areas varied from 0.14 to 2.99 mg/L. Values above the threshold limit of iron (0.3 mg/L) were found in Cummings Lodge, Non-Pariel and Vreedenhoop. Abnormal values of iron can cause stains in light colored clothes, dark discoloration in some food and beverages and unpleasant taste in water.

Lead values from the studied areas varied from 0 to 0.48. Value above the threshold limit for lead (0.01 mg/L) was found at Corriverton. There was no detection for lead in the other areas. Water can be contaminated with lead through corrosion of household plumbing systems and erosion of natural deposits. Abnormal values of lead can cause mental disorder in infants and children. It can also cause kidney problem and high blood pressure in adults. Copper values from the studied area varied from 0.01 to 0.02 mg/L. And all the values were below WHO threshold limit (2.0 mg/L). Zinc values from the studied areas varied from 0.01 mg/L to 0.07 mg/L. And all the values were below the WHO threshold limit (5.0 mg/L) (Fig. 2). Turbidity values from the studied areas varied from 1.1 to 13.5 NTU. Values above the threshold limit of turbidity were found in Non-Pariel and Vreedenhoop.

Water can be contaminated with high level of turbidity through soil runoff. Abnormal values of turbidity can cause nausea, cramps, diarrhea and headache. Salinity values from the studied areas varied from 27.9 to 318. TDS values from the studied areas varied from 42 to 461. And all the values were below the threshold limit of WHO. Temperature values from the studied areas varied from 29.2 to 30. DO values from the studied areas varied from 1 to 8. And all the values were below the threshold limit of W.H.O. EC values from the studied areas varied from 57 to 661. And all the values were below the threshold limit of W.H.O. The pH values from the studied areas varied from 5.66 to 7.5. And all the values were below the threshold limit of W.H.O (Tables 4 and 5, and Fig. 3). Chloride values from the studied areas varied from 11.8 to 174. And all the values were below the threshold limit of W.H.O. Sulphate values from the studied areas varied from 0.15 to 0.79. And all the values were below the threshold limit of W.H.O. There was no value found for nitrate from any of the studied areas.

Anions tested for were chloride, sulphate, nitrate and phosphate. Chloride, Cl^- values ranges from 11.8 mg/L to 174 mg/L. The highest value of 174 mg/L ± 8.09 was recorded at Cummings Lodge and the lowest of 11.8 ± 4.1 mg/L at Non-Pariel. These values are all lower than the WHO value of 250 mg/L. Sulphate, SO_4^{2-} values range from 0.15 mg/L ± 0.0 to 0.20 mg/L ± 0.01. The highest value of 0.79 mg/L ± 0.01 was recorded at Georgetown and the lowest at Vreedenhoop, 0.15 mg/L ± 0.0. These values are significantly less than WHO value of 200 mg/L. There was no detection for nitrate. Phosphate values range from 0.10 to 0.19 mg/L. The highest value of 0.19 mg/L ± 0.01 was recorded at Cummings Lodge and the lowest (0.10 mg/L ± 0.01) at Linden. These values are all less than the WHO threshold limit of 5 mg/L (Tables 6 and 7, and Fig. 4).

Table 2 Triplicate values of the chemical parameters (cations) of selected domestic water

Areas	Sample	Cd	Al	Fe	Pb	Cu	Zn
Corentyne	S1	0.03	0.01	0.08	1.08	0.02	0.09
	S2	0.02	0.01	0.38	0.36	0.02	0.06
	S3	0.01	0.01	0.37	Nd	0.02	0.06
Cummings Lodge	S1	0.01	0.03	2.32	Nd	0.02	0.04
	S2	0.01	0.03	2.30	Nd	0.01	0.04
	S3	Nd	0.03	2.31	Nd	0.01	0.03
Non-Pariel	S1	Nd	0.09	2.99	Nd	0.01	0.03
	S2	Nd	0.07	3.0	Nd	0.01	0.03
	S3	Nd	0.06	2.98	Nd	0.01	0.04
Linden	S1	Nd	0.01	0.31	Nd	0.01	0.04
	S2	Nd	0.06	0.31	Nd	0.01	0.02
	S3	Nd	0.08	0.30	Nd	0.01	0.01
Georgetown	S1	0.04	0.28	0.65	Nd	0.01	0.01
	S2	0.05	0.31	0.65	Nd	0.01	0.01
	S3	0.03	0.29	0.64	Nd	0.01	0.01
Vreedenhoop	S1	0.01	0.03	0.54	Nd	0.01	0.03
	S2	0.01	0.04	0.54	Nd	0.01	0.03
	S3	0.01	0.03	0.54	Nd	0.01	0.03

ANOVA, Analysis of Variance is a statistical method used to determine the significant differences between two or more means [24]. ANOVA is used to test general and not specific differences among means. Table 8 shows whether there is a significant difference between the parameters tested for. Accordingly, since the P values are greater than 0.05, it can be said that there is not a significant difference for the areas tested. Table 9 shows whether there was the significant or non-significant relationship (ANOVA) between areas for cations and anions tested for. Accordingly, since the P values are greater than 0.05, it can be said that there is not a significant difference for the areas tested.

Fig. 5 shows the relationship between the parameters (physical, cations, anions) measured. In statistics, regression analysis is a statistical tool that is used for estimating the relationship among variables [25].

Correlation is a statistical measure that indicates the mutual relationship between two or more variables. There is a positive and negative correlation. A positive correlation shows the extent to which two variables increase or decrease in parallel while a negative correlation indicates the extent to which one variable increases as the other decreases [26]. Table 10 shows correlation relationship between the physical parameters, cation and anions. As Table 10 indicates a positive correlation value of 0.487 mg/L is obtained between aluminium and chloride, whereas a negative Correlation value of 0.25863 mg/L is obtained between aluminium and sulphate.

Table 3 The mean ± standard deviation of the chemical parameters (cations) of selected domestic water

Areas	Cd (mg/L)	Al (mg/L)	Fe (mg/L)	Pb (mg/L)	Cu (mg/L)	Zn (mg/L)
Corriverton	0.02 ±0.01	0.01 ±0.02	0.27 ±0.2	0.48 ±0.4	0.02 ±0	0.07 ±0.02
Cummings Lodge	0.006 ±0	0.03 ±0	2.32 ±0.01	Nd	0.01 ±0	0.03 ±0.01
Non-Pariel	Nd	0.07 ±0.02	2.99 ±0.01	Nd	0.01 ±0	0.03 ±0.01
Wismar	Nd	0.05 ±0.04	0.30 ±0.01	Nd	0.01 ±0	0.02 ± 0.02
Georgetown	0.04 ±0	0.2 ±0.27	0.14 ±0	Nd	0.01 ±0	0.01 ±0
Vreedenhoop	0.01 ±0	0.03 ±0.01	0.54 ±0	Nd	0.01 ±0	0.03 ±0
WHO	0.003	0.2	0.3	0.01	2	3

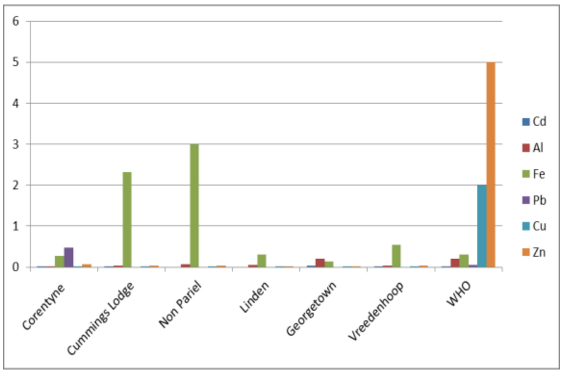


Fig. 2 Corresponding graph showing the mean of chemical parameters (cations) of selected domestic water

Table 4 Triplicate values of the physico-chemical parameters of selected domestic water

Areas	Sample	Turbidity	Salinity	TDS	Temp.	DO	EC	pH
Corentyne	S1	2.7	318	461	29.9	7	661	7.1
	S2	2.7	318	461	29.9	7	661	7.03
	S3	2.7	318	461	29.9	7	661	7.02
Cummings Lodge	S1	1.1	66	98	29.8	4	139	6.11
	S2	1.1	66	98	29.8	4	139	6.09
	S3	1.1	66	98	29.8	4	139	6.13
Non-Pariel	S1	13.5	39.7	59	29.2	1	83	5.66
	S2	13.5	39.7	59	29.2	1	83	5.64
	S3	13.5	39.7	59	29.2	1	83	5.68
Linden	S1	3.4	80.7	119.4	30.0	6	170.7	6.1
	S2	3.4	80.7	119.4	30.0	6	170.7	6.08
	S3	3.4	80.7	119.4	30.0	6	170.7	6.12
Georgetown	S1	3.3	86.1	127	29.7	8	182	7.5
	S2	3.3	86.1	127	29.7	8	182	7.48
	S3	3.3	86.1	127	29.7	8	182	7.52
Vreedenhoop	S1	5.4	27.9	42	29.2	8	57	7.2
	S2	5.4	27.9	42	29.2	8	57	7.18
	S3	5.4	27.9	42	29.2	8	57	7.22

Table 5 The mean ± standard deviation of the physico-chemical parameters of domestic water

Areas	Turbidity (NTU)	Salinity (ppm)	TDS (mg/L)	Temp. (°C)	DO (mg/L)	EC (mg/L)	pH
Corentyne	2.7 ±0	318 ±0	461 ±0	29.9 ±0	7 ±0	661 ±0	7.05 ±0.08
Cummings Lodge	1.1 ±0	66 ±0	98 ±0	29.8 ±0	4 ±0	139 ±0	6.11 ±0.02
Non-Pariel	13.5 ±0	39.7 ±0	59 ± 0	29.2 ±0	1 ±0	83 ±0	5.66 ±0.02
Linden	3.4 ±0	80.7 ±0	119.4 ±0	30.0 ±0	6 ±0	170.7 ±0	7.2 ±0.02
Georgetown	3.3 ±0	86.1 ± 0	127 ±0	29.7 ±0	8 ±0	182 ±0	7.5 ±0.02
Vreedenhoop	5.4 ±0	27.9 ±0	42 ±0	29.2 ±0	8 ±0	57 ±0	7.2 ±0.02
WHO	5		500		13	1800	6.5-8.5

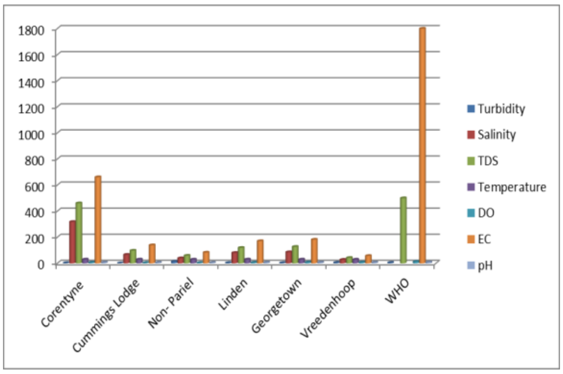


Fig. 3 Corresponding graph showing the mean of physico-chemical parameters of selected domestic water

Table 6 Triplicate values of the chemical parameters (anions) of selected domestic water

Areas	Sample	Cl^-	SO_4^{2-}	NO_3^-	PO_4^-
Corentyne	S1	149	0.21	Nd	0.15
	S2	149	0.20	Nd	0.15
	S3	149	0.20	Nd	0.15
Cummings Lodge	S1	170	0.20	Nd	0.19
	S2	170	0.19	Nd	0.19
	S3	184	0.19	Nd	0.20
Non-Pariel	S1	14.2	0.19	Nd	0.14
	S2	14.2	0.19	Nd	0.14
	S3	7.09	0.20	Nd	0.15
Linden	S1	21.3	0.20	Nd	0.11
	S2	21.3	0.21	Nd	0.11
	S3	21.3	0.20	Nd	0.10
Georgetown	S1	28.4	0.78	Nd	0.15
	S2	28.4	0.80	Nd	0.15
	S3	28.4	0.80	Nd	0.15
Vreedenhoop	S1	45	0.15	Nd	0.13
	S2	45	0.15	Nd	0.13
	S3	46	0.15	Nd	0.13

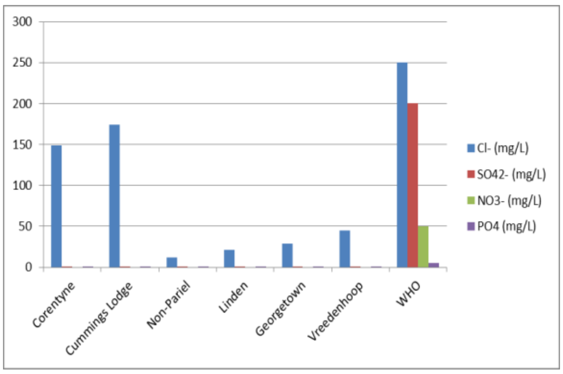


Fig. 4 Corresponding graph showing the mean of chemical parameters (anions) of domestic water

Table 7 The mean ± standard deviation of the chemical parameters (anions) of selected domestic water

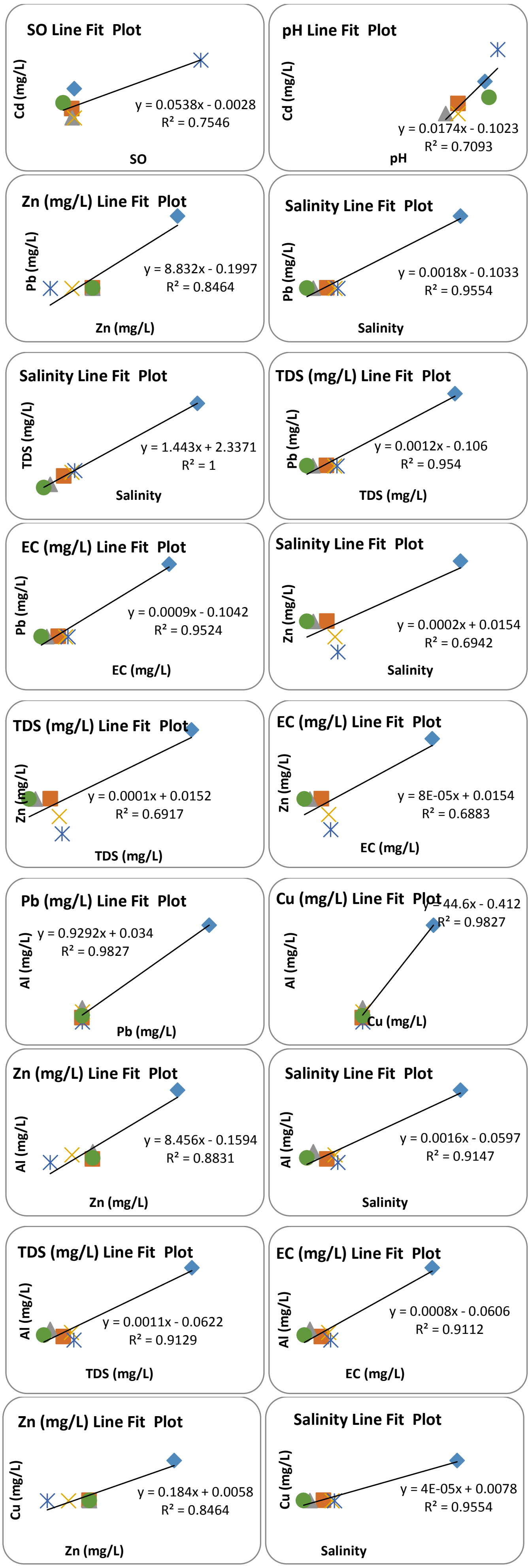
Areas	Cl^- (mg/L)	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	PO_4 (mg/L)
Corentyne	149 ±0	0.20 ± 0.01	Nd	0.15 ±0
Cummings Lodge	174 ±8.09	0.19 ±0.01	Nd	0.19 ± 0.01
Non-Pariel	11.8 ±4.1	0.19 ±0.01	Nd	0.14 ±0.01
Linden	21.3 ±0	0.20 ± 0.01	Nd	0.10 ±0.01
Georgetown	28.4 ±0	0.79 ±0.01	Nd	0.15 ±0
Vreedenhoop	45 ±0.7	0.15 ±0	Nd	0.13 ±0
WHO	250	200	50	5

Table 8 The non-significant relationship between physico-chemical parameters of selected domestic water

Parameters	Correlation values	R^2 values	P-value	Comments
DO vs Cd	0.637059	0.4058	0.173685	Not Significant
DO vs Fe	0.702299	0.4932	0.119747	Not Significant
pH vs Fe	0.487056	0.2372	0.327186	Not Significant
Cl vs Pb	0.534688	0.2859	0.274399	Not Significant
Cl vs PO_4	0.741351	0.5496	0.091697	Not Significant
Salinity vs Cl^-	0.536229	0.2875	0.272751	Not Significant
TDS vs Cl^-	0.536779	0.2881	0.272163	Not Significant
Temperature vs Cl^-	0.433309	0.1878	0.390715	Not Significant
EC vs Cl^-	0.535626	0.2869	0.273395	Not Significant
SO_4 vs Zn	0.560486	0.2519	0.310373	Not Significant
Turbidity vs Cl^-	-0.59929	0.3592	0.20868	Not Significant
Temperature vs Turbidity	-0.74955	0.5618	0.086236	Not Significant
DO vs Turbidity	-0.65699	0.4316	0.156306	Not Significant
Cl^- vs Al	0.486811	0.237	0.327467	Not Significant
Cl^- vs Cu	0.534688	0.2859	0.274399	Not Significant
Cl^- vs Zn	0.616508	0.3801	0.192399	Not Significant
pH vs SO_4	0.560486	0.3141	0.247308	Not Significant
Temperature vs Salinity	0.539825	0.2914	0.268918	Not Significant
Temperature vs TDS	0.542731	0.2946	0.265836	Not Significant
EC vs Temperature	0.545062	0.2971	0.263374	Not Significant

Table 9 The significant and non-significant relationship (anova) between areas

Areas	F	P-value	$F_{critical}$	Comment
Metals	2.3677	0.047232	2.333484	Significant
Corriverton vs Cummings Lodge	2.983659	0.103359	4.493998	Not significant
Metals	1.619234	0.172454	2.333484	Not significant
Corriverton vs Non- Pariel	3.828001	0.06809	4.493998	Not significant
Metals	2.802103	0.023455	2.333484	Significant
Corriverton vs Linden	3.920727	0.06516	4.493998	Not significant
Metals	3.013341	0.016954	2.333484	Significant
Corriverton vs Georgetown	3.870318	0.066734	4.493998	Not significant
Metals	1.403159	0.252898	2.333484	Not significant
Corriverton vs Vreedenhoop	3.639222	0.074546	4.493998	Not significant
Metals	3.265003	0.011671	2.333484	Significant
Cummings Lodge vs Non-Pariel	2.607699	0.125891	4.493998	Not significant
Metals	6.205766	0.000354	2.333484	Significant
Cummings Lodge vs Linden	0.246785	0.626104	4.493998	Not significant
Metals	6.769905	0.000208	2.333484	Significant
Cummings Lodge vs Georgetown	0.080519	0.780235	4.493998	Not significant
Metals	3.780382	0.005672	2.333484	Significant
Cummings Lodge vs Vreedenhoop	3.612309	0.075525	4.493998	Not significant
Metals	8.037692	7.03E-05	2.333484	Significant
Non-Pariel vs Linden	3.25212	0.090194	4.493998	Not significant
Metals	6.910384	0.000183	2.333484	Significant
Non-Pariel vs Georgetown	3.576096	0.076865	4.493998	Not significant
Metals	12.54844	3.53E-06	2.333484	Significant
Non-Pariel vs Vreedenhoop	0.175452	0.68088	4.493998	Not significant
Metals	3.487736	0.008486	2.333484	Significant
Georgetown vs Vreedenhoop	2.588214	0.127213	4.493998	Not significant
Metals	852.7478	2.26E-20	2.333484	Significant
Metals	3.702412	0.006304	2.333484	Significant
Linden vs Vreedenhoop	2.240433	0.153909	4.493998	Not significant



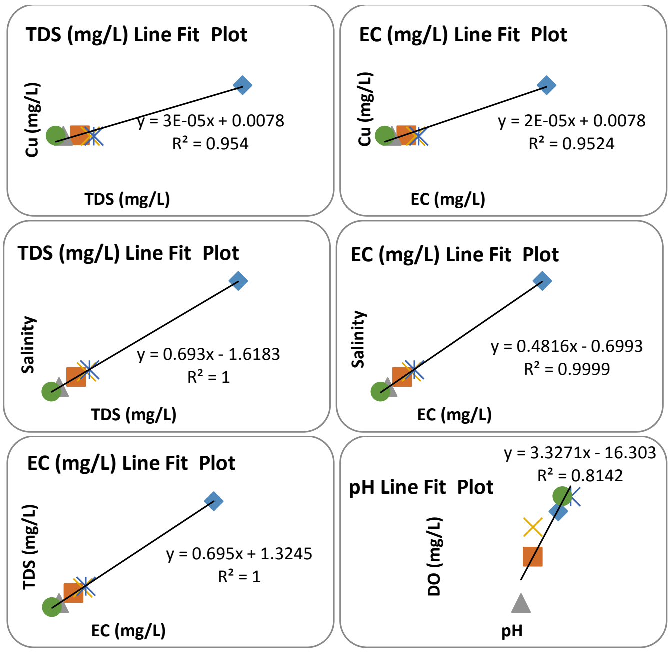


Fig. 5 Regression graph showing relationship between parameters

Table 10 Correlation between the various physical parameters and anion and cation concentration

	Cd (mg/L)	Al (mg/L)	Fe (mg/L)	Pb (mg/L)	Cu (mg/L)	Zn (mg/L)	PO4 (mg/L	Cl	SO	NO	Turbidity	Salinity	TDS (mg/L	Temperatur	DO (mg/L)	EC (mg/L)	pH
Cd (mg/L)	1																
Al (mg/L)	0.126998	1															
Fe (mg/L)	-0.04542	0.056726	1														
Pb (mg/L)	0.234521	0.991307	0.085222	1													
Cu (mg/L)	0.234521	0.991307	0.085222	1	1												
Zn (mg/L)	-0.08102	0.939741	0.140841	0.92	0.92	1											
PO4 (mg/L	0.242438	0.049316	-0.33837	0.11094	0.11094	0.188598	1										
Cl	0.031229	0.486811	0.059663	0.534688	0.534688	0.616508	0.741351	1									
SO	0.868704	-0.25863	-0.31161	-0.1717	-0.1717	-0.50189	0.114474	-0.28022	1								
NO	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1							
Turbidity	-0.37042	-0.14489	-0.41678	-0.24307	-0.24307	-0.0906	-0.26507	-0.59929	-0.18551	#DIV/0!	1						
Salinity	0.320675	0.956386	0.017182	0.977443	0.977443	0.833161	0.111793	0.536229	-0.0394	#DIV/0!	-0.35752	1					
TDS (mg/L	0.321407	0.955465	0.016713	0.976729	0.976729	0.83168	0.111994	0.536779	-0.03795	#DIV/0!	-0.35994	0.999994	1				
Temperat	0.173959	0.330586	-0.03974	0.373002	0.373002	0.158526	0.025863	0.433309	0.147025	#DIV/0!	-0.74955	0.539825	0.542731	1			
DO (mg/L)	0.637059	0.146112	0.702299	0.239046	0.239046	0.011952	-0.20719	0.032986	0.391696	#DIV/0!	-0.65699	0.286473	0.287271	0.285605	1		
EC (mg/L)	0.322787	0.954547	0.014081	0.975897	0.975897	0.829627	0.111565	0.535626	-0.03516	#DIV/0!	-0.36045	0.999974	0.999991	0.545062	0.286958	1	
pH	0.842203	0.192818	0.487056	0.295266	0.295266	0.065664	0.02689	0.042522	0.560486	#DIV/0!	-0.46269	0.313799	0.313783	0.04803	0.902357	0.313302	1

4. Conclusion

Domestic water from Georgetown showed the highest value of 0.04 ± 0.00 mg/L for Cd whereas there was no detection for Non-Pariel and Wismar. Georgetown domestic water also registered the highest for Al (0.2 ± 0.27 mg/L) and the lowest value of (0.03 mg/L) for Cummings Lodge domestic water. Fe recorded its highest value of 2.99 ± 0.01 mg/L for Non-Pariel domestic water, whereas there was no detection of lead in all the water with the exception of Corriverton domestic water which showed a value of 0.48±0.4 mg/L. Cu and Zn registered its highest value for Corriverton domestic water with values of 0.02 ± 0.0 mg/L and 0.07 ± 0.02 mg/L respectively. These values, with the exception of those for Al, Cu and Zn are all higher than the WHO standards for drinking water. The WHO standards for the presence of Cd, Al, Fe, Pb, Cu and Zn in domestic water is 0.003 mg/L, 0.2 mg/L, 0.3 mg/L 0.01 mg/L, 2.0 mg/L and 3.0 mg/L respectively. The pH of the domestic water range from 5.66 to 7.2, whereas the salinity ranges from 28 ppm to 318 ppm. The latter was observed for Corriverton domestic water. TDS registered its highest value of 461 mg/L for Corriverton domestic water, whereas the lowest value of 42±0.00 mg/L was registered for Vreedenhoop water. Where the values are higher (Cd, Fe, Pd) than WHO standards, steps such as educating the residents should be taken to rectify the situation and protect the livelihood of its citizen

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