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Raw and Treated Water Quality at Dalun Water Works, Ghana

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***Abstract* — This paper presents research conducted on the inlet (raw) and outlet water quality at Dalun Water Works in the Northern Region of Ghana. It also assesses the impact of the rock formations underlying the White Volta Basin on the water quality. The research revealed that the rock formation does not have significant influence on the water quality in this area. The major concerns with the quality of inlet or raw water include; high values of turbidity and colour especially in the rainy season. Total iron, total manganese and total coliform recorded significant deviations from the three different standards used as the benchmarks for assessing the water quality. These suggest that the outlet water is not good for consumption and other domestic uses. The treated or outlet water parameters are however within the permissible limits provided by the various organisations and is good for consumption and domestic use.**

Keywords—Water Quality, Dalun Water Works, White Volta Basin

I. INTRODUCTION

The quality of water in the Northern Region of Ghana has been a major concern, given the fact that water borne diseases have been prevalent in the area. Due to these concerns the government of Ghana and many NGO's working in the region have invested resources in their quest for clean potable water for residents of the area. The Ghana Water Company has over the years expanded its capacity in supplying quality water to Tamale and its environs. One of such facilities is the water works located at Dalun, a village in the Kumbungu District of the region. The need for continuous monitoring of water quality entering and leaving this plant is paramount so as to be constantly updated on the efficiency of the plant. There is the need to assess raw water quality to help in configuring the treatment process. The treated water quality is assessed to monitor the water sent to consumers.

The quality of raw water sets the basis for the configuration of water treatment plants. This means that the concentration of the various ions and substances in the water will determine what kind of treatment processes that would be adopted in treating the water. The quality of raw water especially in terms of the ionic concentrations is greatly influenced by the geology or rock formation in the area. The main activity that aid in the release of these ions to the water bodies is the process of weathering and erosion. The end products of the interaction of rock and water in river catchment areas is therefore an assemblage of secondary minerals in soils and sediments and the transfer of these minerals into the water system. In studies relating to river water quality, the transfers of solutes are expressed in terms of biomass uptake, cyclic salt precipitation and chemical weathering of bedrocks (Drever, 1997).

Studies have established that, in the absence of significant human activities that impact on water quality, weathering becomes the major process influencing the quality of water. The human activities on the banks of the White Volta river that serve as the main source of water for treatment at Dalun water works has been relatively minimal. The quality of the raw water here is therefore mainly influenced by the geology, weathering and erosional activities. This research aims at investigating the connection between the raw water quality at Dalun and the geology of the area. Comparisons are made to assess the qualities of both raw and treated water at the treatment plant. The standards employed in this evaluation include; WHO standards, GWCL standards and EPA, Ghana standards for water quality.

II. STUDY AREA

A. Area Location and Accessibility

Dalun water works is located in Kumbungu District in Northern Region of Ghana (Fig. 1). Tolon/Kumbungu District shares border with West Mamprusi District to the North, West Gonja District to the West and South and the East with Savelugu/Nanton District and the Tamale Metropolis. Access to Dalun from the regional capital, Tamale, is via a feeder road.

B. Climate

The climate of the region is controlled by two air masses: the North-East Trade Winds and the South-West Trade Winds. The North-East Trade winds, or the Harmattan, blowing from the interior of the continent, are dry. In contrast, the South-West Trade winds, or the monsoons, are moist since they blow over the seas and are often responsible for rain in the area (Boubacar *et al.*, 2005).

C. Rainfall

There is one rainy season (unimodal) and total annual rainfall of between 1000 mm-1300 mm. The rainy season is between 140 to 190 days in duration (Abdul-Ganiyu *et al.*, 2011). Rains are often torrential.

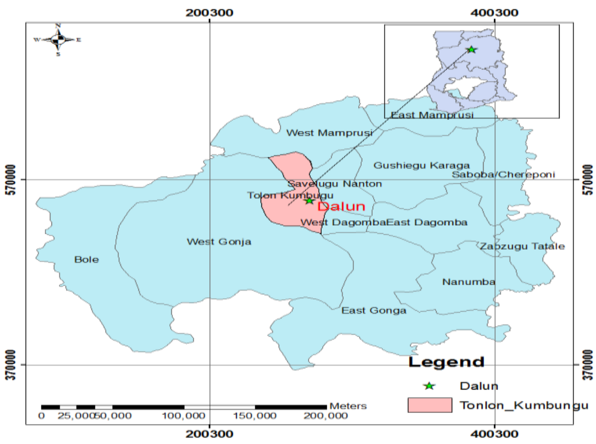


Fig. 1. Map of the Northern Region of Ghana, showing the location of Dalun

D. Topography

The local relief of the White Volta is about 400 m with the maximum altitude of around 600 m in the Gambaga hills in the northeast. The areas of the basin are generally made up of flat lying planes (Andah *et al.*, 2004).

E. Relief

The Basin is flanked by a mountain chain on its westernmost section. The Basin in general has a low relief with altitudes varying between 1 m and 920 m. The average mean altitude of the Basin is approximately 257 m, with more than half the Basin in the range of 200 m to 300 m (Boubacar *et al.*, 2005).

F. Geology of Area

The White Volta Basin is composed of about 45% crystalline rocks comprising the Birimian Supergroup and its associated granitic intrusives and isolated patches of Tarkwaian rocks. The remaining 55% is composed of the Voltaian sedimentary rocks consisting of the Upper Voltaian sandstones, Obosum beds, Oti beds and Basal sandstones (Kesse, 1985).

III. LITERATURE REVIEW

A. Water Quality Analysis

The analyses of various samples of raw and treated water are grouped into four categories and these include; Physical analysis, Metallic analysis, Non-metallic analysis and Biological and Bacteriological analysis.

B. Physical Analysis

1) Alkalinity: Alkalinity of water is defined as the acid-neutralizing capacity of the water. The alkalinity of water is primarily a function of carbonate (CO_3^{2-}), Bicarbonate (HCO_3^{2-}) and Hydroxide (OH-) content and is taken as an indication of the concentration of these constituents. It is a sum of all the titrable bases. Alkalinity is a measure of an aggregate property of water (Balaara *et al.*, 2009).

2) pH: Measurement of pH is one of the most important and frequently used tests in water chemistry. pH is used in alkalinity and carbon dioxide measurement and many other acid-base equilibra. At a given temperature, the intensity of the acidic or basic character of a solution is indicated by pH. The pH value of natural water varies with the geological nature of the source and the presence of dissolved solids.

3) Turbidity: Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter and planktons and other microscopic organic matter. It is an expression of the optical property that cause light to be scattered and absorbed rather than transmitted with no change in direction or flux level through the sample. In general, it is considered that, turbidity values greater than 2 NTU will compromise disinfection efficiency (VIHA pers. comm., 2006).

4) Colour: Colour in water may result from the presence of natural metallic ions, human and animal materials, plant material and industrial waste. The term colour is used to mean the true colour, that is, the true appearance of water from which turbidity has been removed. The term apparent colour include not only colour due to substances in the solution, but also due to suspended matter (Balaara *et al.*, 2009).

C. Metallic Analysis

1) Aluminium: Aluminium is the third most abundant element on earth's crust, occurring in minerals within rocks and clays. This wide distribution accounts for the presence of aluminium in nearly all natural waters as soluble salt, a colloid, or insoluble compound (Balaara *et al.*, 2009).

2) Iron: Some groundwater and acid surface drainage contain considerable amounts of iron. A bitter-sweet astringent taste is detectable by some persons at levels above 1 mg/L. Under reducing conditions, iron exists in the ferrous state (Fe^{2+}). In the absence of complex forming irons, ferric ion (Fe^{3+}) is not significantly soluble unless the pH is very low. On exposure to oxygen Fe^{2+} is oxidised to Fe^{3+} (Balaara *et al.*, 2009). Iron in water can cause staining of laundry and porcelain. The most common soluble iron in water is ferrous bicarbonate. Majority of surface water contain less than 5 ppm of iron (Anon., 2010).

3) Manganese: Manganese occurs in a similar way as iron and is equally dangerous in high concentrations (Anon., 2010).

D. Non-metallic Analysis

1) Chloride: Chlorine in the form of chloride ion (Cl^-), is one of the major inorganic anions in fresh water and waste water. In potable water, the salty taste produced by chloride concentrations is variable and dependent on the chemical composition of water. Some waters containing 250 mg/l of Cl^- may have detectable salty taste if the cation is sodium. Salty taste may be present in waters containing as much as 1000 mg/l chloride when the predominant cations are calcium and magnesium. High chloride content may harm metallic pipes and structures as well as growing plants (Anon., 2011a).

2) Nitrate, Nitrite and Ammonia Nitrogen: In fresh water and waste water, the forms of nitrogen of greatest interest are in order of decreasing oxidation state: nitrate, ammonia, and organic nitrogen. All these forms of nitrogen, as well as nitrogen gas (N_2) are biochemically inter-convertible and are components of the nitrogen cycle. Typical organic concentrations vary from a few hundred micrograms per litre in some lakes to more than 20 g/l in sewage. Total oxidised nitrogen is the sum of nitrate and nitrite nitrogen and generally occurs in trace quantities in surface water but may attain high levels in some ground waters (Balaara *et al*., 2009).

3) Sulphates: These are formed from combination of sulphur and oxygen which forms part of the natural occurring minerals in soil and rock formations. The sulphur dissolves over time and is released into the water. Sulphate minerals can cause scale build-up in water pipe and may be associated with bitter taste in water. They can also have a laxative effect which can lead to dehydration especially in infants (Anon., 2010).

4) Silica: Most natural water contains silica ranging from 1 ppm to 100 ppm. Its presence in higher quantities is deleterious in terms of forming scales on boilers and insoluble deposits on turbine blades (Anon., 2010).

5) Fluoride: Fluoride is usually found naturally in low concentrations in drinking water and foods. Fresh water supplies usually contain 0.01 ppm to 0.03 ppm of fluoride. The chief source of fluoride in water is from the mineral fluorite (Anon., 2011b).

E. Biological and Bacteriological Analysis

1) Feacal Coliform: Presence of faecal coliform in water indicates that, the water has been polluted with faeces of humans or other warm-blooded animals. Coliform group consist of several genera of bacteria belonging to the family enterobacteriaceae. In this research, lactose fermentation method was used to test for their presence. At 37 ºC, the bacteria ferment lactose to form gas and acid within 48 hours.

2) Escherichia Coliform Bacteria (E. coli): The presence of this type of bacteria shows that the water may contain pathogens. These make the water quality not good enough for consumption. These pathogens are found in the intestine of warm blooded animals and are present in their excreted faecal matter. The levels of these bacteria in water could rise due to presence of humans or animals around water source. E. coli is measured in counts per 100 millilitres.

3) Biological Oxygen Demand (BOD): This is a measure of how much oxygen is consumed by bacteria as they breakdown pollutants and organic matter in water. BOD is measured by observing the levels of dissolved oxygen in a sealed sample over a five day period (Schanz, 2010).

IV. RESEARCH METHODOLOGY

F. Data Collection

Data was obtained from the daily analysis conducted by the Quality Assurance Division of the Ghana Water Company Limited, Tamale. Most parameters in the analyses were measured two to three times daily and the daily average obtained. Other parameters were measured at different intervals within a month. These parameters were averaged and recorded for each month.

In the laboratory, titration was the main method used to determine alkalinity, pH and total hardness. The turbidity was measured using HACH 2100P Turbidimeter. The concentrations of the ions were measured using the HACH DR/2000 spectrophotometer and HACH DR/2800 spectrophotometer.

G. Data Analysis

The arithmetic averages of the parameters were calculated over a period of one month to obtain representative values for each month. Parameters like pH, turbidity, conductivity, colour, total hardness, alkalinity, residual chlorine and temperature were all measured on daily basis, therefore the average for each month was obtain by estimating the arithmetic average for each parameter. The rest of the parameters apart from those mentioned above were analysed three times within the month and averaged. The tables and graphs below show the data analysed and the water quality comparison with the standards.

V. DISCUSSIONS

Three standards were used as basis to evaluate quality of the intake (raw) water and the treated water. These include; World Health Organisation (WHO) standards, Ghana Water Company Limited (GWCL) standards and Environmental Protection Agency (EPA) standards.

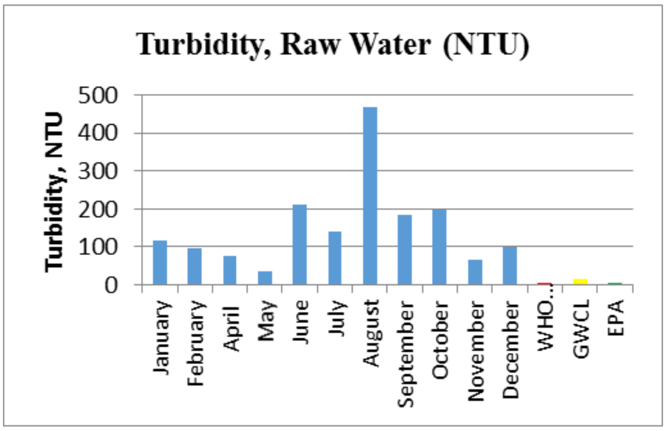
A. Raw Water

Turbidity of the raw water recorded throughout the year was above the limits of all three standards used (Appendix A). The turbidity peaked in August corresponding to the peak of the rainy season. A cyclic trend is observed in the values of turbidity where it peaks at August and steadily reduces till May then starts to rise again. This cycle corresponds to the rainfall patterns in the Northern part of Ghana.

Total iron concentrations from June to December exceeded the limits of all three standards. The key process responsible for the release of iron into the river channel is believed to be weathering. Runoff after precipitation leads to physical weathering and paves way for faster chemical weathering regimes. Iron commonly exists in the weathered materials as oxides and hydroxides.

The colour of raw water is above all permissible limits for all the months except April and May where values are within the range of GWCL standards. These values nonetheless, were above the limits provided by WHO and EPA. The high values recorded for colour may be indication of high amounts of organic matter in water. Colour of the water has similar trend to turbidity, therefore the increased colour can be attributed to runoff.

Results also revealed that, total manganese concentration in the water for all months excluding April was above the EPA permissible limits. The manganese concentration for January and August again exceeded limits set by all the standards. The values recorded for total solids, total dissolved solids, total soluble solids, faecal coliform and total coliform were significantly high especially during the rainy season. This is directly attributed to the surface run-off and erosion of organic matter and weathered sediments into the water. Apart from the parameters discussed above, other parameters recorded for raw water were well within the permissible limits.



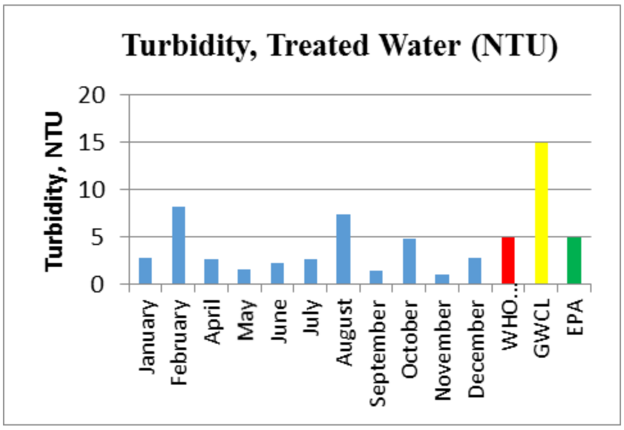
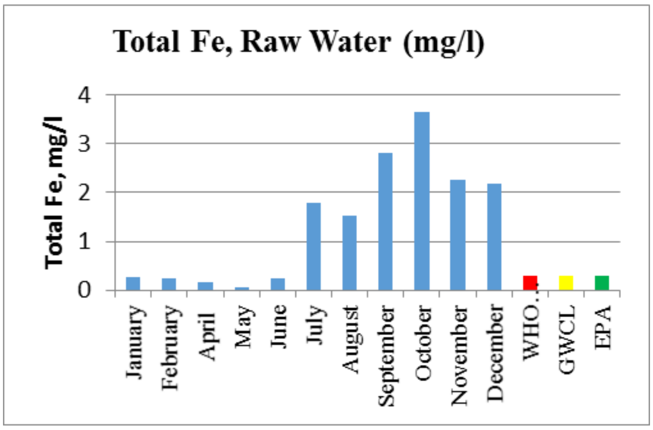


Fig. 2 and 3: Bar chart comparing the turbidity in raw water and treated water to standards provided by WHO, GWCL and EPA.



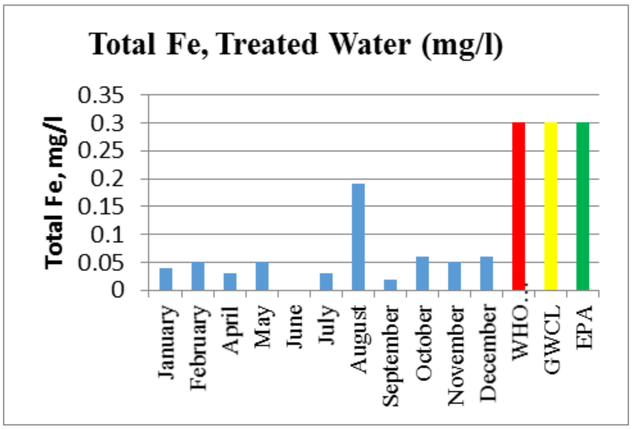


Fig. 4 and 5 Bar chart comparing the concentration of iron in raw water and treated water to standards provided by WHO, GWCL and EPA.

B. Treated Water

For the treated water, there were few cases in which the values were above maximum or below minimum permissible limits. Some of the observations made on the treated water are summarised below.

The turbidity values recorded in February and August, 8.16 NTU and 7.37 NTU respectively (From Appendix B) were above the WHO and EPA limits but within the permissible limits set by GWCL. The possible explanation of this is that, the optimum amount of Alum (Al_2SO_4), used in treatment plant is set to satisfy only the GWCL limit. The other standards are not of much considered during treatment at Dalun Water Works.

The values recoded for total manganese (0.165 mg/L and 0.479 mg/L) in the months of January and June respectively were above the EPA limit of 0.1 mg/L as presented in Appendix A. These isolated cases may have resulted from a local factor of manganese release (weathering and release of manganese from a manganese-rich rock) into the water of which the treatment process did not reduce to acceptable limits as per EPA.

In July, the average pH was below the minimum allowable limit to 4.81, meaning the water during this period was mildly acidic. Juxtaposing this to the pH of the raw water, low values of pH were recorded during the same period. This may be directly related to the geology of the drainage area of the river. Reaction between water and rock can result in the formation of acid and therefore lower pH values for the water.

Apart from the parameters discussed above, the other parameters recorded for treated water were well within range therefore giving no cause for alarm. The treated water on the average is found to be good for drinking.

VI. CONCLUSIONS

Based on the results obtained from the data analysis of tests conducted on the raw and the treated water, the following conclusions can be drawn.

- The treated water quality generally meets the approved standards set by the various organisations. Treated water therefore, is good for drinking and other domestic purposes.
- The quality parameters of the raw water generally do not meet the standards used. The raw water is therefore not good enough for drinking and domestic purposes.
- Fresh and slightly weathered rocks do not yield significant amounts of ions into water to affect its quality. The fresh rock formations therefore have relatively less influence on the quality of the water.
- Weathered products of rocks have greater influence on the quality of the raw water. Most parameters for raw water that exceeded permissible limits resulted from leached and eroded portions of weathered rock products into the stream channel.
- Concentrations of ions and the levels of other parameters, especially for the raw water increased significantly during the rainy season. This means, high cost of treatment during the rainy season.

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APPENDIX A: Raw (inlet) water parameters in comparison to Permissible limits of drinking water provided by WHO, GWCL and EPA.

Parameters	Months											Guidelines		
	Jan	Feb	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	WHO	GWCL	EPA
pH	6.57	6.55	7.27	5	6.07	5.26	7.25	6.97	7.08	6.74	7.38	6.5-8.5	5-8.5	6.5-8.5
Temperature	24.3	27.4	32.6	32.9	32.6	30.4	29.8	30.3	31.2	32	27.5			
Conductivity	78	77.3	77	114.8	70.6	92.8	54.9	58	75.1	84.6	80.4			1500
Turbidity	117	97.2	77	35.9	210	141	468	184	199	65.5	98.3	5	15	5
Colour	88.5	75.5	47.3	22.2	156	55	209.5	172.5	125	72	112.5	15	50	15
Total Alkalinity	33	30	38	9	35	20	23	20	35	35	47			200
Total Hardness	29	26	21	17	14	21	12	17	15	16	15	500	500	500
Calcium Hardness	21	18	13	10	9	17	10	14	12	9	11			500
Magnesium Hardness	8	8	8	7	5	4	2	3	3	7	4			500
Calcium	8.4	7.2	5.2	4	3.6	17.4	4	5.6	4.8	3.6	4.4	200		
Magnesium	1.944	1.944	1.944	1.701	1.215	0.972	0.486	0.729	0.729	1.701	0.972	150		
Total Iron	0.28	0.24	0.17	0.05	0.25	1.8	1.52	2.82	3.66	2.25	2.17	0.3	0.3	0.3
Total manganese	0.569	0.204	0.085	<0.001	0.433	0.477	0.778	0.474	0.244	0.17	0.184	0.5	0.5	0.1
Zinc	0.01	0.02	0.06	0.11	0.04	0.03	<0.01	0.13	0.15	0.08	0.05			
Copper			<0.01		0.07	0.09	0	0.07	<0.01	0	<0.01			
Aluminium	<0.001	0.106	0.204	0.71	0.245	1.147	0.339	0.165	0.241	0.105	0.153			5
Chromium						0.09	<0.01	<0.01	0.02	0	<0.01			0.1
Lead	<0.001	<0.001												0.1
Arsenic	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.1	<0.1	<0.01	0	<0.01			0.5
Cynide						0.003	0.009	<0.01	0.04	0.006	<0.001			1
PO4	0.1	0.16	0.09	0.16										
Silica	0.013	0.205	0.112	0.133	0.041	7.43	0.004	7.85	6.75	4.93	3.55			
Chloride	9	10	7	10	10	10	27	11	11	14	18	250	600	250
Fluoride	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0	<0.01	1.5	1.5	1
Sulphate	1	1	1	35	1	15	0	1	1	1	5	400	400	400
Sulphide		0.103	0.218	0.02	0.523	0.279	0.863	0.723	0.202	0.077	0.14			1.5
Ammonia Nitrogen	1.02	0.86	0.05	0.66	2.04	1.91	2.83	2.48	1.38	0.97	1.41			1
NO2 Nitrogen	<0.001	0.011	0.006	<0.001	<0.001	0.022	0.048	0.015	0.003	0.002	0.005	1		
NO3 Nitrogen	0.05	0.04	0.04	0.04	<0.01	<0.01	<0.01	0.03	0.03	0.04	<0.01	10		50
TDS	26.4	30.7	38.5	57.6	35.3	40.5	27.5	29	37	42.3	41	1000	1000	1000
Total solids	96.4	91.7	83.5	84.6	179.3	235.5	404.5	273	150	107.3	97			
T.S.S	70	61	45	27	144	195	377	244	113	65	56			50
Total Coliform	780	2400	290	2.28	390	350	940	3120	1680	1510	480			400
Feacal Coliform	240	970	160	1100	2720	1400	530	1650	930	620	2400			

APPENDIX B: Treated (outlet) Water Parameters in Comparison to Permissible Limits of Drinking Water provided by WHO, GWCL and EPA.

Parameters	Months											Guidelines		
	Jan	Feb	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	WHO	GWCL	EPA
pH	6.2	7.03	6.85	6.73	7.12	4.81	6.22	6.04	6.73	6.83	7.31	6.5-8.5	5-8.5	6.5-8.5
Temperature	24.4	26.4	32	32.1	32	30.3	29.3	30	31.1	31.8	26.7			
Conductivity	94.5	104.8	102.8	103.2	108.2	112.4	102.7	102.2	101.2	103.2	114.1			1500
Turbidity	2.72	8.16	2.65	1.57	2.26	2.63	7.37	1.43	4.86	1.06	2.77	5	15	5
Colour	1.2	0	1	0.3	2.3	0.6	6	0.3	1.8	2.6	3.72	15	50	15
Total Alkalinity	21	25	27	34	21	14	11	15	10	16	25			200
Total Hardness	24	24	22	18	20	28	15	24	18	17	17	500	500	500
Calcium Hardness	22	24	16	13	13	23	12	18	12	10	15			500
Magnesium Hardness	2	0	6	5	7	5	3	6	6	7	2			500
Calcium	8.8	9.6	6.4	5.2	5.2	9.2	4.8	7.2	4.8	4	6	200		
Magnesium	0.486	0	1.458	1.215	1.701	1.215	0.729	1.458	1.458	1.701	0.486	150		
Total Iron	0.04	0.05	0.03	0.05	<0.01	0.03	0.19	0.02	0.06	0.05	0.06	0.3	0.3	0.3
Total manganese	0.165	0.032	<0.001	<0.001	0.479	<0.001	0.092	0.027	<0.001	0.024	<0.001	0.5	0.5	0.1
Zinc	<0.01	<0.01	0.01	0.02	0.01	0.03	0.01	0.01	0.01	0.03	0.02			
Copper			0.03		0.03	<0.01	0.08	0.05	<0.01	0	0.03			
Aluminium	<0.001	0.086	0.148	0.133	0.097	0.204	0.543	0.281	0.241	0.091	0.14			5
Chromium						0.02	<0.01	<0.01	0.03	0.02	0.02			0.1
Lead	<0.001	<0.001												0.1
Arsenic	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.1	<0.1	<0.01	0	<0.01			0.5
Cynide						0.001	0.005	<0.01	0.003	0	0.003			1
PO4	0.1	0.01	0.09	0.12										
Silica	0.01	0.134	0.083	0.072	<0.001	9.28	0.011	9.92	7.73	11.91	10.35			
Chloride	6	9	10	9	11	14	9	15	17	15	15	250	600	250
Fluoride	<0.01	<0.01	<0.01	<0.01	<0.01	0.08	<0.01	<0.01	<0.01	0	<0.01	1.5	1.5	1
Sulphate	8	7	20	18	23	34	29	29	31	26	28	400	400	400
Sulphide		0.005	<0.001	0.002	<0.01	0.011	0.007	0.018	0.013	0.004	0.006			1.5
Ammonia Nitrogen	0.01	<0.01	0.1	0.02	<0.01	<0.01	0.08	0.02	0.09	0	<0.01			1
NO2 Nitrogen	0.006	0.008	0.001	<0.001	0.001	0.002	0.006	0.002	<0.001	0	0.002	1		
NO3 Nitrogen	0.04	0.03	0.03	0.04	0.03	0.15	<0.01	0.07	0.05	0.07	0.02	10		50
TDS	47.3	52.4	51.3	51.6	54	56.9	50.9	55.1	50.4	51.4	57	1000	1000	1000
Total solids	48.3	63.4	55.3	61.6	58	60.9	59.9	67.1	56.4	51.4	59			
T.S.S	1	11	4	10	4	4	9	12	6	0	2			50
Total Coliform	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1			400
Feacal Coliform	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1			
Residual Chlorine	2.3	0.09	1.2	1.8	2	2.5	1.75	1.1	2.4	0.75	1.7			

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