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GROUND WATER QUALITYAND ITS PHYSICO-CHEMICAL NATURE AT TEN MILES, CHIBOMBO DISTRICT, ZAMBIA

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ABSTRACT

The formation of high salt deposit upon heating the water taken from the ground to analyse the Physico-Chemical parameters and to assess the reliability of drinking water quality within the vicinity of Chibombo region in Ten Miles, Zambia at model site. The parameters include water temperature, rain fall, weather conditions, humidity, colour, odour, turbidity, total suspended solids, total dissolved solids, pH, electrical conductivity, dissolved oxygen (DO), chemical oxygen demand (COD), total alkalinity, hardness, biological oxygen demand (BOD) and minerals studies have been analysed throughout the year 2014 .The results showed that some of the parameters like turbidity, odour and colour are at acceptable limit. The total hardness and the total dissolved solids are not within the permissible limit due to seasonal variation and increased environmental pollutants. It was found that the hardness was high due to the calcium and magnesium mineral contents such as Iron is high with little traces of Copper due to availability of copper deposit at many provinces and leaching from salty rocks beds. It is observed that the water is not suitable for drinking and special attention must be drawn to execute water softener technology such as RO or any other sophisticated ion exchange system is needed for domestic purpose.

This research paper discusses and reports the prevailing conditions of water around Ten Miles region, Chibombo district, Zambia.

KEY WORDS: Ground water, Turbidity, pH, TDS, TH, EC, pH, Minerals, BOD, COD and RO.

I. INTRODUCTION

Among all the natural resources, water is the most precious, and life is indispensable without water [29] [14]. Groundwater is utilised for many purposes, one of the important scopes is drinking water [1]. Only 1% of the ground water is available as drinking water [12] [23]. As per World Health Organisation (WHO) direction the Africa also comes under the purview of water quality monitoring especially the Zambian region [13] [16] [29]. Although Zambia may have sufficient water during the rainy season, many catchment areas are not properly protected [11]. The ground water quality is not up to the limitation [16]. Each year the urbanisation and industrialisation lead contamination level high in nearby urban areas. [6]. Water, sanitation and hygiene factors are responsible for 11.4 percent of all deaths in Zambia [9]. The lack of data about groundwater resources also has implications for climate change research and policymaking [10]. These uncertainties are critical since the climate system and groundwater storage is fundamental, integrated parts of the hydrological cycle and, in turn, of all life on Earth [7].

II. GEOGRAPHICAL INFORMATION

Ten Miles is in the Chibombo District, situated in the central part of the Zambia. Zambia is the nation that is in the southern Africa and it is also referred to as the republic of Zambia [6]. It has Angola on the west; Namibia, Zimbabwe, Mozambique and Bostwana on its south; Tanzania on its north east and Congo on its north. Lusaka is the capital city of Zambia and it is located on the south east side of the nation. Zambia the land locked nation is the world's 39th largest country [17]. The Chibombo province is surrounded by other provinces like kabwe, Chisamba, Lusaka, Chongwe, and Kafue. The nearby rivers are Lunsemfwa and Kabiri. The highest point in Zambia is the Mafinga hills that are 2031 m. The lowest point is the Zambezi River [8].

2.1 Climate

The climate conditions of Zambia are tropical in nature. The rainy season conditions of Zambia are November to April [17] [18]. Zambia also experiences periodic drought and tropical storms during October to April [7]. Annual rainfall averages 1010 mm (range 750–1400 mm) and increases progressively from south to north. The terrain of Zambia is characterised by high plateau, some hills and mountains.

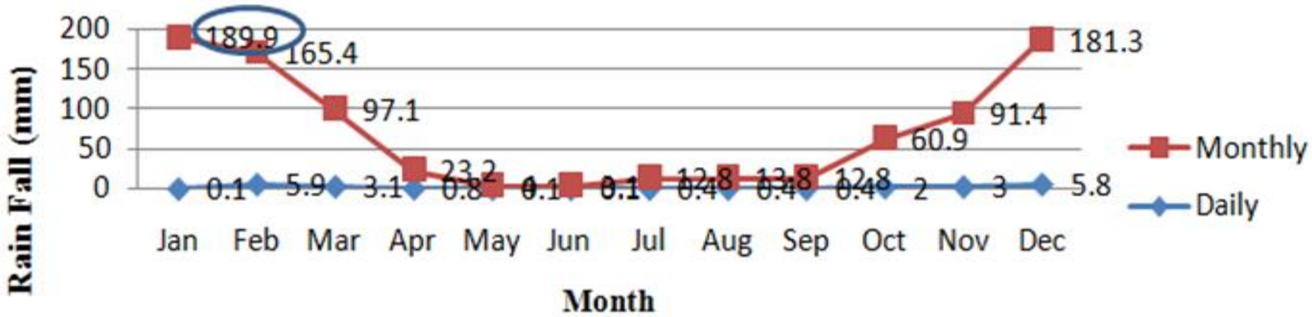
Table: 1 ***Sample collection, average temperature and rain fall (2014)***

Sample Collection Time	*Average Water Temperature (°C)*		*Average Rain Fall (mm)*		*Average Snow Days*	*Average Fog Days*
	Warmest	*Coldest*	*Daily*	*Monthly*		
Jan-10/1/2014-12:18 To 12.30 Hrs	*27*	*17.3*	*0.1*	*189.9*	*0*	*3*
Feb-12/2/2014-12:30 To12.40 Hrs	*27*	*17.4*	*5.9*	*165.4*	*0*	*4*
Mar-20/3/2014-11:30 To 11.40 Hrs	*27*	*16.5*	*3.1*	*97.1*	*0*	*3*
Apr-15/4/2014-11:15T0 11.45 Hrs	*26.5*	*14.4*	*0.8*	*23.2*	*0*	*1*
May-13/5/2014-12:30 To 12.45Hrs	*25.2*	*11.4*	*0.1*	*4.0*	*0*	*1*
Jun-16/6/2014-10:45 T0 11.00 Hrs	*23.7*	*13.1*	*0.1*	*3.1*	*0*	*2*
Jul-11/7/2014-11:45 T0 11.50 Hrs	*23.5*	*8.7*	*0.4*	*12.8*	*0*	*1*
Aug-7/8/2014-12:20 T0 12.35 Hrs	*26.1*	*10.9*	*0.4*	*13.8*	*0*	*0*
Sep-11/9/2014-11:35 To 11.50 Hrs	*29.8*	*14.5*	*0.4*	*12.8*	*0*	*0*
Oct-5/10/2014-12:00 To 12.15 Hrs	*31.3*	*17.1*	*2.0*	*60.9*	*0*	*0*
Nov-12/11/2014-11:40 T0 11:50 Hrs	*29.8*	*17.6*	*3.0*	*91.4*	*0*	*0*
Dec-20/12/2014-11:20 To 11.30Hrs	*27.3*	*17.5*	*5.8*	*181.3*	*0*	*1*

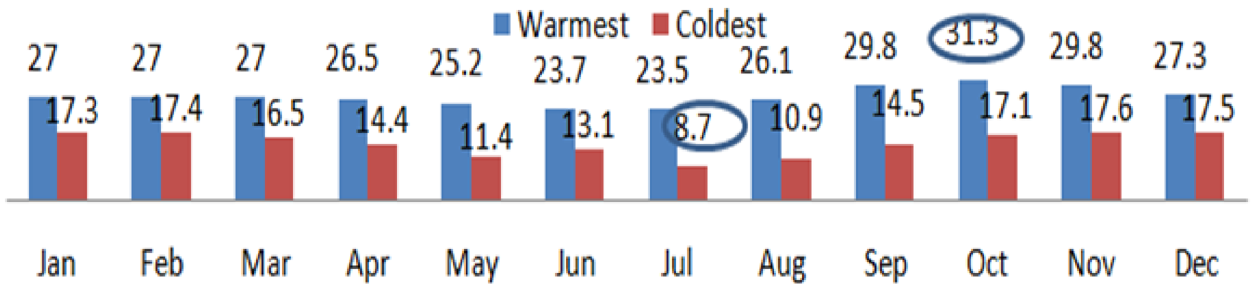
Graphical representation of Average Weather Condition

2.2 Weather Condition

October is the warmest with an average temperature of 31.3°C at noon. July is the coldest with an average temperature of 8.7° C at night. In winter there may be some days it freezes, overall winters are mild in temperature, with the coldest month most of



being July. July is on average the month with most sunshine. Rainfall peaks around January. The time around June is driest [4] [5].



Rainfall and Snow fall data are taken from the reliable sources.

Fig: 1 Average rain fall (2014)

Fig: 2 Average temperature variations (2014)

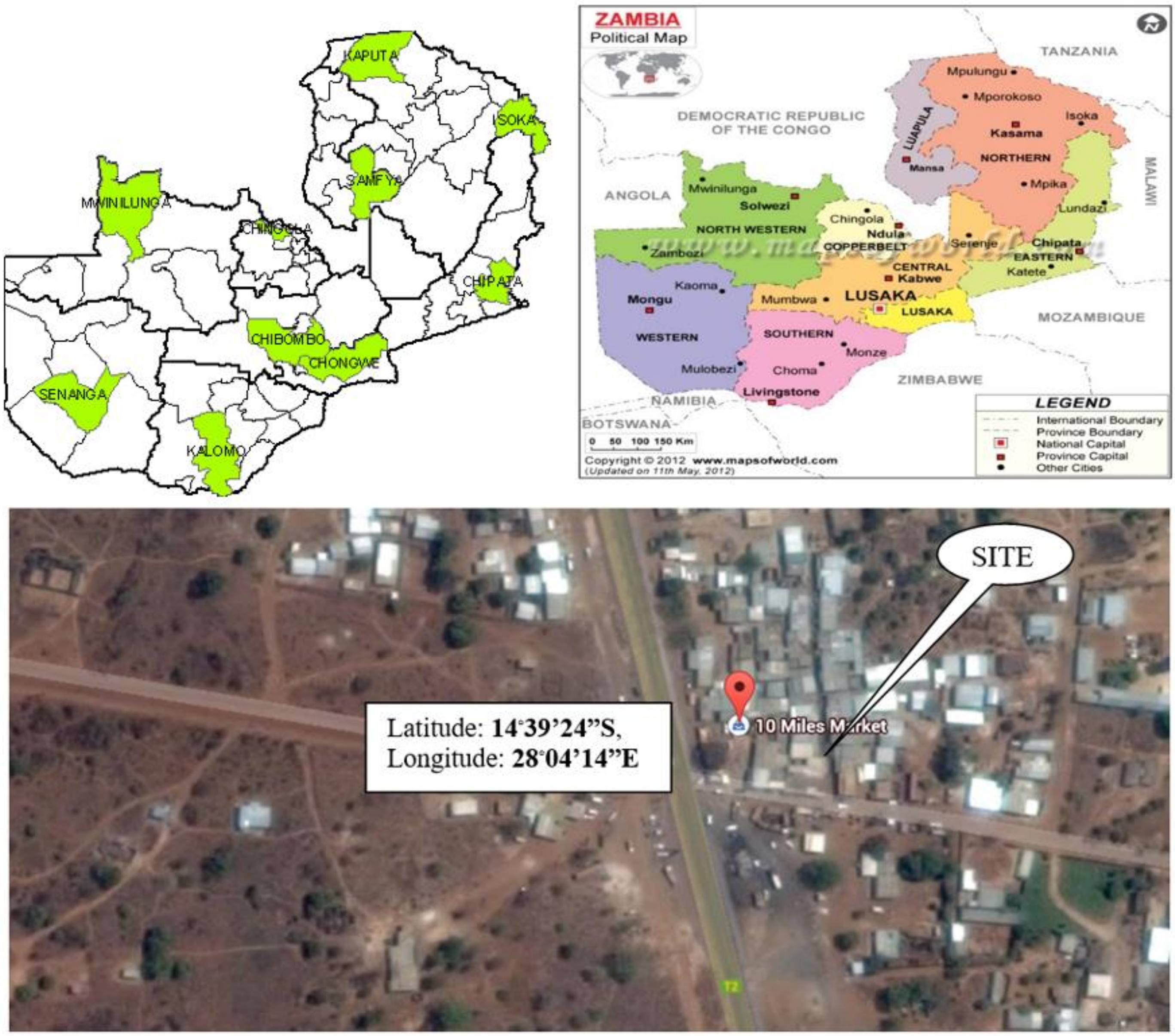
III. MATERIALS AND METHODS

3.1 Study Area

The study area has latitude: **14°39'24" S**, Longitude: **28°04'14" E,** Elevation above sea level=1156m, Altitude: 3792 ft. The latitude and longitude of Zambia covers a total area of 752,614 square kilometres [4].

Ten Miles is in the Chibombo District, situated in the central part of the Zambia. Zambia is the nation that is in the southern Africa and it is also referred to as the republic of Zambia [6]. It has Angola on the west; Nambia, zaimbabwe, Mozambique and Botswana on its south; Tanzania on its north east and Congo on its north. Lusaka is the capital city of Zambia and it is located on the south east side of the nation.

Figure:3 Map shows the study area of Ground water at Ten Miles, Chibombo Dt, Zambia



3.2 Sample Collection

To assess the Ground water quality in Ten Miles, Chibombo district, Zambia, two sites has been chosen. One of the sites is *free dry land* in which there is not much utilisation of water for domestic purpose. Another one is surrounded by *crowded residential area*. The later in which the utilisation of ground water is high. The ground water sample is collected at various time periods in every month. Most probably the collection time lies between 11.00 Hrs To 12.30 Hrs. The Average Weather parameters such as Water temperature, rain fall, humidity, snow fall, and fogs are notified separately. The physicochemical characteristics included temperature, colour, conductivity, turbidity, total dissolved solids (TDS), total suspended solids (TSS) and total solids (TS). The chemical characteristics included alkalinity, hardness, pH, dissolved oxygen (DO), minerals (Ca, K, Mg, Fe, Na, Cl_2, SO_4, Si, PO_4, NO_3, Total organic carbon, chemical oxygen demand (COD) and biological oxygen demand (BOD)[19]. The samples were pre-treated in the field to fix the samples and immediately brought to the laboratory for an on-spot physical and chemical analysis of various parameters following the standard methods [14]. Following is the various physiochemical natures of ground water at site I & II which is compared with WHO parameters of drinking water guidelines [19].

The water temperatures at the time of collection were noted and kept in the laboratory in which the room temperature was maintained at 25°C. For comparative purpose, in each month, at random time period, the ground water sample drawn from different nearby provinces were subjected to basic physico-chemical analysis which is summarised in below table 3.

3.3 Physical Method of Experimental Verification

The 100 ml of the sample water in the month of January was subjected to heating for 15 minutes in a hot plate at 100°C. The initial total dissolved solid was chemically estimated as 2995mg/L. In a physical method of verification an approximately 100 ml sample was subjected to heating, in which the total salt deposit was estimated gravimetrically 120 mg/100 ml approximately.

Figure:3 Pictures showing salt deposit after heating in the filter paper
1. Before Boiling 2.During Boiling 3. After Boiling 4. Filter Paper 5.Filtering Boiled Water 6.Salt Deposit 7.Heating Beaker to Dryness

IV.RESULTS

Table: 2 Statistical data on original physiochemical nature of ground water at site I & II Ten Miles

C-Colour **O**-Odour **TU**-Turbidity (NTU) **DO**- Dissolved Oxygen (Mg/L)
pH-H^+ ion concentration **EC**-Electrical Conductivity (Mho^{-1}) **TDS**-Total Dissolved Solids (Mg/L)
TH-Total Hardness (CaCO3) ppm **BOD**-Biological Oxygen Demand (Mg/L)
COD-Chemical Oxygen Demand (Mg/L) **N/A**-Not Applicable **WHO**-World Health Organisation.

Year 2014 ***Physicochemical Parameters***

	Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	WHO
C	S^1-					Colour Less								N/A
	S^2-					Colour Less								N/A
O	S^1-					Odour Less								N/A
	S^2-					Odour Less								N/A
TU	S^1-	2.8	2.5	2.3	2.1	2.1	2.2	2.0	1.9	2.1	2.5	2.4	2.6	5
	S^2-	2.9	2.6	2.6	2.6	2.4	2.1	1.9	2.0	2.2	2.2	2.3	2.5	5
pH	S^1-	8.6	8.3	8.1	8.0	7.9	7.9	7.5	7.9	7.5	7.8	7.8	8.5	7-8.5
	S^2-	8.8	8.8	8.5	8.3	8.3	8.2	8.2	8.3	8.0	8.0	8.0	8.3	7-8.5
EC	S^1-	1900	1870	1830	1835	1825	1750	1700	1658	1705	1743	1880	1889	1400
	S^2-	2200	2150	2125	2098	1998	1990	1850	1902	1977	1993	2002	2114	1400
TDS	S^1-	2980	2820	2780	2665	2550	2440	2300	2600	2690	2777	2878	2956	500
	S^2-	3010	2979	2776	2456	2450	2300	2287	2698	2788	2798	2987	2999	500
TH	S^1-	1690	1566	1455	1367	1299	1220	1098	1334	1477	1569	1598	1646	500
	S^2-	1800	1780	1678	1601	1588	1400	1345	1444	1545	1690	1758	1798	500
DO	S^1-	4.9	4.5	4.5	4.7	4.3	4.3	4.1	4.6	4.6	4.7	4.8	4.8	5
	S^2-	3.9	3.7	3.7	3.5	3.6	3.5	3.3	3.4	3.5	3.5	3.8	3.8	5
BOD	S^1-	12.1	12.0	11.4	11.6	11.4	11.5	11.3	11.7	11.9	11.6	11.9	12.0	6
	S^2-	13.8	13.3	13.0	12.8	12.7	12.5	12.3	12.6	12.8	12.9	13.0	13.6	6
COD	S^1-	20.9	17.9	19.8	15.4	16.9	13.8	10.1	14.6	18.8	17.9	20.2	19.0	10
	S^2-	26.9	24.3	25.9	23.7	22.8	20.6	17.5	18.8	22.7	21.2	25.9	26.0	10

Table: 3 Statistical data on Mineral contamination at Site I & II Ten Miles Area

Year 2014		Physicochemical Parameters												WHO
Month		JY	FY	MH	AT	MY	JN	JU	AU	SR	OR	NR	DR	
Ca^+	S^1	280	230	198	225	198	240	210	245	256	265	298	260	100
	S^2	388	340	323	299	310	345	290	367	354	321	347	378	
Mg^+	S^1	187	178	125	123	167	110	101	134	123	167	153	176	150
	S^2	220	199	210	178	145	165	143	178	188	159	202	149	
Na^+	S^1	120	111	99	103	79	88	69	89	76	110	96	115	200
	S^2	146	140	135	123	111	99	79	88	130	126	105	141	
K^+	S^1	75	64	67	58	62	59	55	61	67	70	74	69	12
	S^2	34	32	38	29	42	38	30	40	29	28	27	37	
NO^{3+}	S^1	4.5	4.2	4.6	4.6	4.1	4.8	3.9	3.5	4.5	3.7	2.6	4.2	50
	S^2	3.7	3.5	3.2	3.3	4.0	4.3	3.8	3.7	3.2	2.9	4.1	3.9	
Cl^-	S^1	45	42	67	45	55	59	46	44	47	52	55	49	250
	S^2	51	68	78	59	69	78	61	62	67	74	63	70	
Cu^{2+}	S^1	1.01	0.09	0.07	0.04	0.07	0.08	1.0	0.07	0.08	0.09	0.07	0.05	1.0
	S^2	1.05	1.07	1.09	1.06	1.06	1.08	0.07	1.05	1.08	1.07	1.09	1.09	
Cd^{2+}	S^1	Traceability is Nil ppm												0.005
	S^2													
Ar^{2+}	S^1	Traceability is Nil ppm												0.05
	S^2													
SO_4^{2-}	S^1	32	15	19	21	29	19	12	19	17	21	26	28	250
	S^2	23	20	12	10	19	12	21	18	10	16	16	14	
PO_4^{3-}	S^1	0.5	0.4	0,7	0.7	0.9	0.6	0.8	0.6	0.6	0.9	0.9	1.0	0.1
	S^2	1.2	2.2	0.9	0.8	1.5	1.3	1.1	1.0	0.9	1.4	1.2	1.1	
Fe^{2+}	S^1	0.19	0.15	0.12	0.91	1.05	1.03	0.59	0.66	0.45	0.34	0.65	0.77	0.1
	S^2	1.0	0.99	0.78	0.65	0.67	1.1	1.05	0.79	0.99	0.96	0.88	0.84	

Table: 4 Average Comparative Studies of Physico-chemical Parameters at other provinces of Zambia

Year 2014

Average Physico chemical values	Parameters	Ten Miles	Lusaka	Kasama	Solwezi	Livingstone	Chipata
	Tur	2.12	1.8	3	3.5	1.5	2.0
	pH	8.1	7.9	7.5	8.5	7.4	7.8
	EC	1575	970	1267	1300	1280	1100
	TDS	1916	1250	1587	1865	1660	1390
	DO	4	7.5	6.8	4.5	5.8	6.4
	BOD	12	13.8	15.2	14.8	19.6	7.6
	COD	20	28	19	23	15	21.3

Figure: 4 Average Physico-Chemical Parameter at different provinces

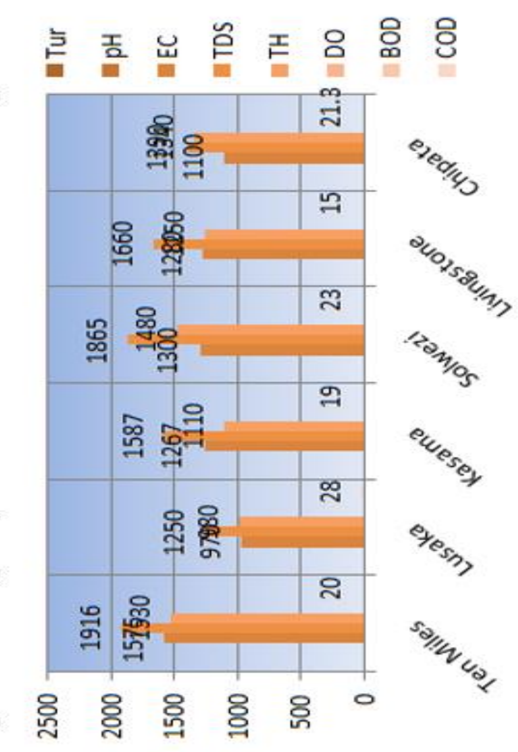


Figure:5 Turbidity and pH Correlation Bar Chart (Site I & II) Ten Miles

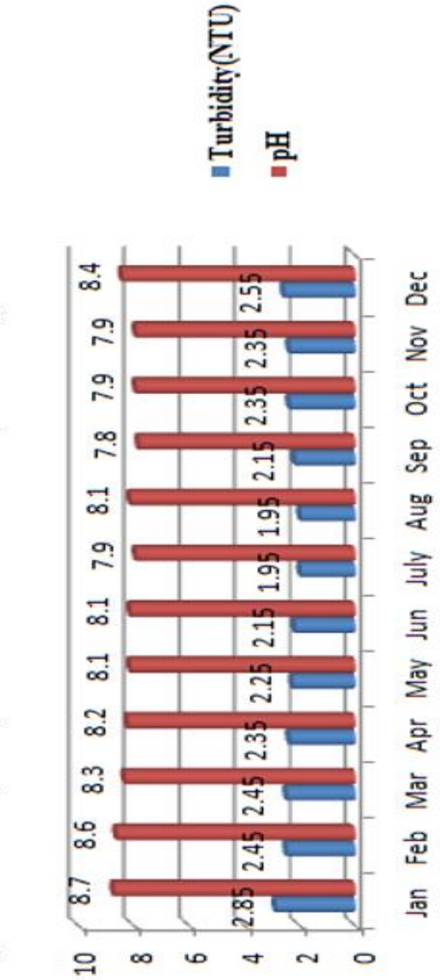


Figure:6 Average DO, BOD and COD Correlation Bar Chart (Site I & II) Ten Miles

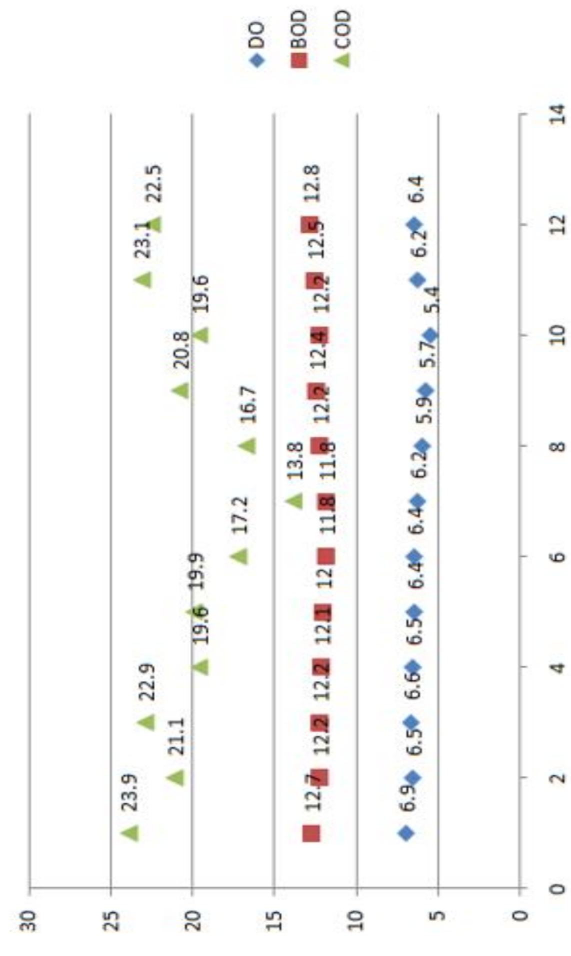
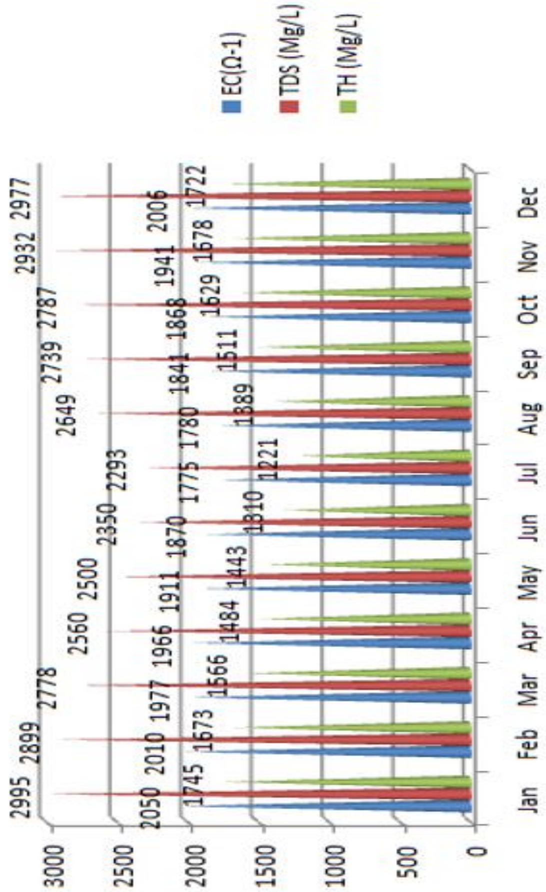


Figure:7 Average EC, TDS and TH Correlation Bar Chart (Site I & II) Ten Miles



V.DISCUSSION

5.1 Turbidity and Hydrogen Ion Concentration (pH)

There are not much turbidity differences in the result, of which January is the highest and July is the lowest turbidity. The highest pH value is (8.7) recorded in the month of January and lowest pH value is recorded in the month of September (7.8). The pH value with respect to the seasonal variation shows that the water is moderately alkaline in the present day study which is in the permissible limit of pH (6.5 to 8.5 for multiple uses of water) as prescribed by WHO [13]. The pH is regulated by the CO_3^{2-}, HCO_3^- system [1] [19]. The relatively higher values of pH in monsoon months coinciding with maxima of total rainfall may be attributed to the considerable dilution of water which increased the buffering effects of the systems.

5.2 Total Dissolved Solids Electrical Conductivity and Total Hardness

The taste and odour of the water is mainly due to the presence of dissolved solids. It is also responsible for the high alkalinity and high hardness [14]. The TDS varies in the research from a maximum value of 2977 to 2293 mg/L which shows that the water cannot be recommended for drinking purpose [13]. The data not only indicates that the water quality but also an information about the mineral deposits in the earth crust [6] [16]. It is linked with health issues and scale forming capacity over pipelines of domestic water supply. The EC is always associated with TDS in the sense that a higher value will tend to increase the EC [14] [16] [40].

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5.3 Total Hardness

The hardness property of water is due to the presence of Ca^{2+} and Mg^{2+}salts in the form CO_3, HCO_3, SO_4, NO_3, and Cl_2 [2]. The cationic part is responsible for hardness because when water is combined with CO_2 to form very weak carbonic acid an even better solvents result [1]. As water moves through the soil and rock [14], it dissolves very small amount of minerals and holds them in solution. The degree of hardness becomes greater as the calcium and magnesium content increases and is related to the concentration of multivalent cations dissolved in the water [3] [4]. Hard water is not a health risk, but a nuisance because of mineral build up on fixtures and poor soap and/or detergent performance [1]. The level of hardness was found to be highest value of (1745 mg/L) in the month of January and lowest value of (1221mg/L) in the month of July, which does not come in the WHO water quality parameters and guidelines [13].

5.4 Dissolved, Biological and Chemical Oxygen demand (DO, BOD and COD)

Dissolved Oxygen content of the water observed in the site shows not much deviation. The average DO content lies between 6.9 to 5.4 mg/L with respect to the seasonal variation which comes under WHO guidelines [13]. The aquatic species like fish can survive in this nominal DO content. The variation is low when the season nears the summer and become high in winter and other seasons [4]. The BOD of the microorganism is found to be maximum (12.8ppm) in the month December and minimum (11.8ppm) in the month of July

5.5 Phosphate- Phosphorus (PO_4^{3-} – P) and Nitrate- Nitrogen (NO_3^- -N)

As decomposition of plants and animal material occurs, dissolved oxygen levels decrease and nitrate level increase [8]. In addition, bacteria break down large protein molecules into ammonia which combines with dissolved oxygen to form nitrates and nitrites, of this, nitrates is considered for water quality [14]. There is a correlation between Nitrate, Phosphate and DO.
An increase in nitrates may be followed by an increase in phosphate. As phosphates increase and the growth of aquatic plants is encouraged, algal blooms can occur [24] [25]. With the increase in algae growth and decomposition, the dissolved oxygen levels will decrease [13]. It was realised that the variation in nitrate content of water ranged from 2.9 to 4.3 mg/L and phosphate content of water ranged from 0.9 to 2.2 mg/L of which nitrate only meet the parameter.

5.6 Traces of Minerals

All the minerals which is present in the ground water is causally linked with human metabolism, even a small ppm of minerals may cause vitamin deficiencies in human growth. The Copper deposit in the study area is due to the leaching of rainwater from the copper deposited hill provinces in and around the district. The copper is found to be a maximum of 1.09 mg/L and does comes under the prescribed parameter, the K^+ and Na^+ minerals are found to be maximum of 42 mg/L and 120 mg/L respectively, of which sodium alone obey the parameters. Cl^- and $SO4^{2-}$ minerals having the maximum value of 67 mg/L and 32 mg/L respectively, which fulfil the WHO guidelines [13]. Iron (Fe^{2+}) having a maximum existence of 1.1 mg/L does not meet the WHO and EPA (Environmental production agency) water quality Guidelines. There is no traceability of intoxicating substances like Cadmium and Arsenic.

VI. CONCLUSION

As a conclusion that one of our life saving factors is getting deteriorated day by day, and what happens in 10 years and the multiples of years if these issues are ignored and not put forward to the society. The study area of Ten Miles at model site is not much polluted by human activities compared with the urban areas. High deposit of salts and hardness is the fore frontier problem of this site. But whenever there is urbanisation [4], there is a chance of high contamination. The research does not include the pathogenic and other water prone disease-causing bacteria and viruses in the water quality [8] [9]. It was realised that the residential area can utilise a RO (Reverse Osmosis) system as a remedy for high deposition of dissolved salts and high hardness at least for time being [2], but the municipal authorities of Zambia [10], Lusaka can implement a water softener technology at provinces and rural areas with the aid of UNESCO, WHO, NGOs and other international agencies, private and public partnership. A pilot project should be implemented to assess the economic cost associated with the technology [14] [15] [16].

VII. ACKNOWLEDGEMENT

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