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SAND DAMS AS SOURCES OF WATER AND ITS SUITABILITY FOR RURAL COMMUNITIES DURING DRY SEASON AROUND MAKURDI SEMI ARID ZONE, NIGERIA

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ABSTRACT

Water is one of the most plentiful and essential compound for living organisms and plants all over the world. Millions of people in other parts of the world struggles with problems of water supply during periods of low rainfall and dry season where water supply is extremely low. Rural communities especially in Africa who dwell around seasonal streams rely on sand dams. Sand dams store water in shallow depths along dry stream and river beds, are fetched by scooping out sand. An assessment of existence of sand dams in some communities in the outskirt of Makurdi, Benue State was done. Riverbeds used as viable sand dams were identified; 16 physico-chemical parametres were analyzed to determine the water quality. Turbidity, TC, Fe and Mn, were above the threshold, pH, Cl, Ca, Mg, K, were within the threshold limit and TDS, Nitrate, TH, EC, were within acceptable limits. The overall water quality index was found to be 22.89 which is rated as very poor quality. It is recommended that water from sand dams be treated before it is use for drinking and domestic uses. Sand dams should be constructed using modernized structures to increase water storage which will invariably provide and preserve enough clean water throughout the dry season.

Keywords: Sand dams, Riverbeds, Dry season, Water supply, Rural communities, Makurdi.

1. INTRODUCTION

Water retaining structures intercept or obstruct the natural flow of water in wet seasons and store water for drier periods. Water harvesting technologies, which concentrate precipitation through runoff and storage for beneficial use, have been in use since 9000 BC (Oweis and Hachum, 2009). A specific type of groundwater dam, sand storage dams are well known in the Middle East, south-western United States and northern Mexico since the mid-1800s, and Namibia for water supply (Rolf *et al.*, 2008). More recent efforts include small-scale projects in many parts of the world, notably India, Africa and Brazil (Rolf *et al.*, 2008). Such dams store sufficient quantities of water for livestock, minor irrigation and domestic use. The technology might be considered 'simple' but 'effective', the reason why many Non-Governmental Organizations (NGO) consider it an interesting instrument to provide drinking water to poor, rural communities (Nilsson, 1988; Van Haveren, 2004; Rolf *et al.*, 2008).

Many sand dams is being constructed in at least twenty dry land countries including Angola, Namibia, Zimbabwe, Swaziland and Mozambique; Mali, Tanzania, Uganda, Ethiopia, Sudan, Somalia and Somaliland; Ghana, Burkina Faso, Cameroon and Chad(Figure 3); Yemen and Jordan; India and Brazil. Several sand dams in Kenya dated between 1900 and 1945.

Only in the last 15 years have sand dams been the subject of significant wider adoption and research (Nilsson, 1988; Van Haveren, 2004), but most of these sand dams have been built over the past 25 years by community groups supported by CBO Utooni Development Project (since 1980) and Kenyan NGOs, and Africa Sand Dam Foundation since 2010. Presently, it is estimated that there are 2,000 - 2,500 sand dams in Kenya(Eytan, and Spuhler,(2020). Many parts of the world cope with problems of water supply during periods of low rainfall and consequent low or no river discharge in so many ways(Adedayo, 2019). In the dry season, water scarcity is always a problem, most especially in developing countries (Kendra, 2018).

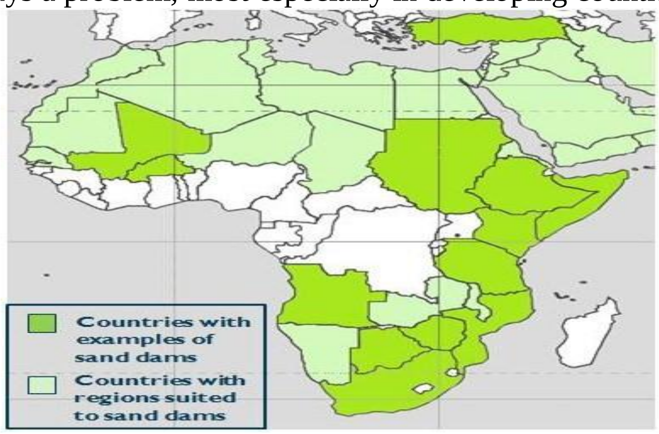

Figure 3: Sand Dams in Africa

Dry lands are at the frontier of some of the world's most critical human and environmental problems: water and food insecurity, climate change, desertification, conflict, displacement and loss of biodiversity worsen the problem(EPA,2012).

The realization of this potential requires significant and sustained investment in soil and water conservation, of which appropriate rainwater harvesting technologies, such as sand dams, are a fundamental element, which brings the need for the assessment of sand dams as dry season water sources that curtails the long hours wasted waiting for scooped water, using traditional methods in river bed sand dams (Gijsbertsen,2007; Hussey, 2007).

Designing sand dams is an art as well as a science and understanding how seasonal rivers flow is the only way to design a successful sand dam. This depends on local knowledge and experience as sand dams can't just be designed in offices by experts, or by pure calculation. (Nissen-Petersen,2006;Tyler,2017). The success requires expert who are experienced in sand dam and their involvement with end-users to place them at the heart of the decision-making processes, local knowledge and correct application and/or adaptation of sand dam technology (Rolf *et al.*, 2008; De Trincheria, 2017).

Makurdi metropolis is in a sub-region where, during the dry season, communities in rural areas almost completely rely on water abstraction through hand-dug wells (scoop holes) in the dry sand riverbeds. To increase water availability during the dry season, construction of sand dams which has turned out to be very successful in increasing groundwater storage capacity, prolonging the period of groundwater availability (bridging dry seasons) and improving water quality (Borst and de Haas, 2006; SSWM, 2020) will highly help to reduce water scarcity among the riverine rural dwellers (Hut *et al.*, 2008; Tortajada, 2020).

Sand dams has never been given attention in Nigeria, but they are extensively patronized by people living in rural areas, especially those close to seasonal rivers, that have no alternative to any sources of water.

2.MATERIALS AND METHODS

2.1 Study Area

Makurdi lies between latitudes 7°44'27.96" and 7°52'27.96"N of the equator and longitude 8°30'43.56" and 8°41'43.56"E of Greenwich meridian. During rainfall, a lot of runoff is recorded that end up in the Rivers and this can be utilized in form of irrigation. It is therefore anticipated that through irrigation there will be production even during the dry season and that the farmers will be able to market their produce during such times. The area lies in the Northern Guinea Savannah agro-ecological zone and with an average rainfall of between 1077-1140mm the area can be said to be agriculturally productive as it produces a variety of crops-cassava, soybean, guinea corn, yams, sesame, rice and groundnuts for the country (NMI, 2017).

2.1.1 Sand dams and water sampling

The most common water resources around the study sites are boreholes and wells that have been dug by individuals in the homesteads. However, rural dwellers around the outskirts of the town relied on sand dams as their sources of water. Some of the sand dams were identified at various outskirts around Makurdi town, after field visits.

Five sand dams were purposely selected based on the objectives of the study. The sites are, Ahum(UniAgric road), Anchow Agu(Lafia road), Bee Swange (Gboko road), Fatee seasonal river(Naka road), and Jamu (North bank) sand dams, labelled as Site(S) S1, S2, S3, S4 and S5 respectively(Plate 1) and located as shown in Table 1. Most of the sand dams are on riverbeds and water is obtain by continues scooping of sand whenever the accumulated water in the scooped hole is fetched out completely. The depth of each hole increases depending on the rate of daily water draw down, which invariably determines the rate of sand scooping. Thus, the rate of depth increase down the wells increases with advance into the dry season taking the form of shallow wells (Table 2).

2.1.2 Sample collection and laboratory analysis

Water samples were collected from the selected sites in one litre plastic bottles in duplicates, after thoroughly cleaned with distilled water and rinsed with water sample prior to collection. In the scoop holes, samples were collected by immersing the sampling containers into the dug wells after scooping out and allow fresh water to seeps in the wells (Table 2). A total of 20 water samples were collected within the study period(Plate 2), according to standards procedures(APHA/AWWA/WEF, 2017).

Soil analysis such as the physical properties of the scooped soil at the site were determined by look and feel method with respect to the depth. Properties such as soil colour, soil structure, soil texture, sediment profiles, were tested using the look and feel method(Table 2).

Sixteen (16) physiochemical parameters of water were determined viz: colour, odour, temperature, turbidity, total dissolved solids (TDS), pH, Iron (Fe), Chloride (Cl), Calcium (Ca), Magnesium (Mg), Potassium (K), Manganese (Mn), Nitrate (NO_3), Total hardiness (TH),

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Electrical conductivity (EC) and Total coliform (TC) using standard laboratory procedures(APHA/AWWA/WEF,2017), materials methods and instruments as shown in Table 3.

2.1.3 Water Quality Index of the Sand Dams

Water quality index (WQI) is a means by which water quality data is summarized for reporting to the public in a consistent manner. It is similar to the ultra violet (UV) index or an air quality index, and it tells us, in simple terms, what the quality of drinking water is from a supplied drinking water(Bora and Goswami, 2017). Thus,WQI shows the composite effect of physiochemical parameters.

WQI scores are computed for each public water supply system that has been sampled in a sampling season using WQI software. Concentrations of elements analysed from the water samples are used in the computation of the WQI for all public water supply systems.

However, if a public water supply system is on a Boil Water Order, or it has a current contaminant exceedance, or average above the drinking water quality guideline, a WQI score is not computed (Bora and Goswami, 2017). The WQI is a summary tool and is not used to replace detailed analysis of drinking water quality standard data. The monitoring and analysis of drinking water quality is to protect drinking water safety on a proactive basis.

The mathematical expression for WQI used was given by Bora and Goswami (2017) as:

$$WQI = \frac{\sum Q_n W_n}{\sum W_n} \qquad 1$$

Where:

Q_n is the quality rating of *n*th water quality parameter,

W_n is the unit weight of the *n*th water quality parameter.

Plate S1: Ahum

Plate S2: Anchow Agu,

Plate S3: Bee Swange,

Plate S4: Fatee River,

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Plate S5: Jamu

Plate 1: Sand Dam Sites

Plate 2: Sampled Water from the Sand Dams

The quality rating Q_n is calculated using the equation(Bora and Goswami, 2017):

$$Q_n = 100\left[\frac{(V_n - V_i)}{(V_s - V_i)}\right] \qquad 2$$

Where:

V_n is the actual amount of *n*th parameter present(analyzed from the laboratory),

V_i is the ideal value of parameter [V_i = 0, except for pH (V_i = 7) and DO (V_i = 14.6 mg/l)]

V_s is the standard permissible value for the *n*th water quality

Unit weight W_n is calculated using the formula;

$$W_n = \frac{k}{V_s} \qquad 3$$

Table 1: Sand Dam Sampling Sites and Water Abstraction Methods

Location/Area	Sampling Points	Site Coordinates	Abstraction method
Ahum, UniAgric road	S1	76.00m above sea level (asl) N 7º 46’32.24” E 8º 36’17.85”	Scooping
Anchow Agu, Lafia road	S2	142.99 m asl N 7º 53’20.92” E 8º 35’22.50”	Scooping
Bee Swange, Gboko road	S3	94.35 m asl N 7º 43’51.18” E 8º 41’26.91”	Scooping
Fatee River, Naka road	S4	78.62 m asl N 7º 41’44.33” E 8º 27’06.90”	Scooping
Jamu	S5	97.93 m asl N 7º 46’01.33” E 8º 34’53.76”	Scooping

Table 2: Monthly Scoop Depth of the Sand Dams

S/No	Site	Scoop depth (m)				Types of Soil layers
		December 2019	January 2020	February 2020	March 2020	
1	S1	0.17	0.19	0.20	0.22	Sandy
2	S2	0.80	0.83	0.91	0.95	Sandy loam
3	S3	0.67	0.70	0.73	0.80	Sandy
4	S4	0.96	1.01	1.20	1.25	Clayey
5	S5	0.45	1.50	1.70	1.82	Sandy clay

Table 3: Laboratory Methods of Analysis and Instruments used.

S/n	Parameters	Units	Methods of Analysis	Instrument(s) used
Physical				
1	Odour	-	Perceive	Glass beaker/Nostrils
2	Colour	Pt-co	Colorimetric	Colorimeter
3	Temperature	^oC	Probe metre	Glass bulb Thermometer
4	Turbidity	NTU	Photo metre	Turbidimeter
5	TDS	mg/l	E.C. Metre	TDS metre
	Chemical and Microbiological Parameters			
1	pH	1- 14	pH Electrode	pH metre.
2	T. Hardness	mg/l	Phenanthroline	AAS*
3	T. Iron (Fe)	$CaCO_3$	Argentometry	AAS
4	Chlorides (Cl)	mg/l	Titrimetric	AAS
5	Calcium (Ca)	mg/l	Titrimetric	AAS
6	Magnesium (Mg)	mg/l	F. Photometry	ECP**/AAS
7	Potassium (K)	mg/l	F. Photometry	AAS
8	Manganese (Mn)	mg/l	Cd-Reduction	Iron Electrode
9	Nitrate (NO_3^-)	mg/l	Titrimetric	AAS
10	E. Conductivity	mg/l	E.C. Metre	Conductivity metre
11	Total coliform (Cfc)	µS/cm Counts/ml	Membrane filtration	Lab reagents/Instruments

AAS* = Atomic absorption spectrophotometer; ECP** = Electrochemical Probe.

where k is the constant of proportionality and it is calculated using the equation:

$$k = \left[\frac{1}{\sum \frac{1}{V_s} = 1,2,\ldots\ldots n}\right] \quad (4)$$

3. RESULT AND DISCUSSION

3.1 Results

The results of the physicochemical analysis of water samples taken from Ahum, Anchow Agu, Bee Swange, Fatee river, and Jamu sand dams, for four months are shown in Tables 4 – 8. The mean water quality parameters of the study sites for four dry season months(December, January, February and March) in relation to the standard values of the World Health Organization (WHO, 2015), the European Union (EU, 2017) and the Nigeria Standard for Drinking Water Quality (NSDWQ, 2015) are shown in Table 9.

3.2 Discussion

3.2.1 Physical parameters

Temperatures varied from 20 to 31˚C for all the four months the study was carried out. The observed slight difference in the four months was that of February and it was due to the fact that temperature tends to be higher in the month of February. The five sand dam sites namely S1, S2, S3, S4, and S5 had a mean ± SD value of 26.75 ± 0.5, 27.50 ± 1.73, 26.58 ± 1.35, 23.75 ± 2.99,

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and 28 ± 2 respectively (Table 9) and it could be due to weather variations occasioned by the distinctiveness of the two main seasons in Nigeria. The permissible limits of WHO, EU, NSDWQ were not indicated due to the reason that, water has different uses and purposes (Figure1), but the variations in values are climatic depended, (Igbinosa *et al*, 2012). The results of colour varied from light brown to colourless for the four different months, the values of WHO, EU and NSDWQ were not indicated, but according to the NSDWQ 2015 documents, drinking water must be colourless, however, the inhabitants have no alternative sources, therefore, the water colour is acceptable.

Odour varied from 'acceptable' odours to 'odourless' for the different sand dam locations. The observed difference in the odours was due to the fact that these sand dams were located in areas full of vegetation, hence, on decaying are susceptible to odours. The permissible odour given by WHO, EU and NSDWQ are odourless. Bee Swange, Anchow Agu, and Jamu sand dams fluctuated between 'acceptable, and 'unacceptable'. Turbidity varied from 1.5 to 785 NTU with mean ± SD value of 26.50 ± 2.99, 117.05 ± 66.77, 456.43 ± 365.68, 19.63 ± 12.20, and 215 ± 18.11 for the five sand dam sites(S1, S2, S3, S4, and S5) respectively. Turbidity value was above WHO, EU and NSDWQ Standards values (Table 9) (Figure 2). Higher turbidity value recorded may be due to increase in water level resulting from increased precipitation, increased soil detachment and increased transportation of detached soil particles through different soil minerals(Elsokkary and Abukila,2014).

Total dissolved solid (TDS) varied from 11 to 865mg/l with mean ± SD value of 44.25 ± 22.35, 99.18 ± 68.51, 488.68 ± 431.36, 52 ± 18.78, and 220 ± 57.14 for the five sand dam sites namely S1, S2, S3, S4, and S5 respectively; the values were below WHO value of 1000mg/l and NSDWQ value of 500mg/l, the EU value was not indicated. This is in agreement with the study of Raman *et al.* (2009). The reduction of TDS content might also be due to the purifying/ filtering of impurities by the sand, referred to as sand filter.

3.2.2 Chemical parameters

The pH showed relative variation of 6.3 to 6.8 for the various months, this can be considered basic and might be unsuitable for domestic consumption with the mean ± SD value of 6.58 ± 0.13, 6.55 ± 0.21, 6.53 ± 0.21, 6.58 ± 0.15, and 6.63 ± 0.15 for the five sand dam sites namely S1, S2, S3, S4, and S5 respectively (Table 9) which might be due to the multi- variable activities on the sand dams during the course of the year and conformed reasonably with standard limits of WHO, EU and NSDWQ (Figure 3) .

Table 4: Monthly Concentration of Water Parameters from Ahum, Uni-Agric Road (S1).

S/No	Parameters	Units	Months				Mean ± SD
			Dec.	Jan.	Feb.	March	
1	Colour	Pt.co	LB*	LB	CL**	CL	-
2	Odour	-	Acceptable	Odourless	Odourless	Acceptable	-
3	Temperature	˚C	27	26	27	27	26.75 ± 0.5
4	Turbidity	NTU	34	30	32	10	26.50 ± 2.99
5	TDS	mg/l	59	52	55	11	44.25 ± 22.35
6	pH	-	6.6	6.6	6.4	6.7	6.58 ± 0.13
7	Iron	mg/l	0.34	0.32	0.42	0.32	0.35 ± 0.05
8	Chloride	mg/l	1.41	1.33	0.22	1.12	1.02 ± 0.55
9	Calcium	mg/l	17	15	1.23	15	12.06 ± 7.28
10	Magnesium	mg/l	0.34	0.22	10	0.00	2.64 ± 4.91
11	Potassium	mg/l	1.1	1.0	0.21	0.20	0.63 ± 0.49
12	Manganese	mg/l	0.001	0.001	1.0	0.00	0.25 ± 0.50
13	Nitrate	mg/l	49	46	0.01	20	28.75 ± 23.17
14	TH	mg/l	22	22	43	20	26.75 ± 10.87
15	EC	$\mu S/cm$	2.26	2.36	20	180	51.16 ± 86.30
16	TC	Count/ml	125	135	128	110	123.75 ± 10.54

LB* = Light brown, CL** = Colourless.

Table 5: Monthly Concentration of Water Parameters from Anchow Agu, Lafia Road (S2).

S/No	Parameters	Units	Months				Mean ± SD
			Dec.	Jan.	Feb.	March	
1	Colour	Pt.co	B***	DB****	B	DB	-
2	Odour	-	Acceptable	Acceptable	Acceptable	Unacceptable	-
3	Temperature	˚C	28	25	29	28	27.50 ± 1.73
4	Turbidity	NTU	87.8	85.7	217	77.7	117.05 ± 66.77
5	TDS	mg/l	59	92	198	47.7	99.18 ± 68.51
6	pH	-	6.8	6.6	6.5	6.3	6.55 ± 0.21
7	Iron	mg/l	0.36	1.00	1.00	0.31	0.67 ± 0.38
8	Chloride	mg/l	0.01	0.01	0.01	4	1.01 ± 1.20
9	Calcium	mg/l	0.7	0.6	0.04	0.00	0.34 ± 0.37
10	Magnesium	mg/l	0.00	0.00	0.00	0.00	0 ± 0
11	Potassium	mg/l	3.1	3.00	3.2	2.5	2.95 ± 0.31
12	Manganese	mg/l	0.001	0.10	0.01	0.00	0.03 ± 0.05
13	Nitrate	mg/l	48	46	45	25	41 ± 10.74
14	TH	mg/l	15	20	18	5	14.50 ± 6.66
15	EC	$\mu S/cm$	105	100	98	95.1	99.53 ± 4.17
16	TC	Count/ml	126	205	204	72	151.75 ± 64.78

B*** = Brown, DB**** = Dark brown.

Table 6: Monthly Concentration of Water Parameters from Bee Swange, Gboko Road (S3).

S/No	Parameters	Units	Months				Mean ± SD
			Dec.	Jan.	Feb.	March	
1	Colour	Pt.co	DB****	CL**	DB	DB	-
2	Odour	-	Unacceptable	Unacceptable	Unacceptable	Unacceptable	-
3	Temperature	˚C	27.5	24.7	26.5	27.6	26.58 ± 1.35
4	Turbidity	NTU	785	73.7	214	753	456.43 ± 365.68
5	TDS	mg/l	867	850	193	44.7	488.68 ± 431.36
6	pH	-	6.8	6.5	6.5	6.3	6.53 ± 0.21
7	Iron	mg/l	1.01	1.00	1.01	0.59	0.90 ± 0.21
8	Chloride	mg/l	39	0.01	36	37	28 ± 18.70
9	Calcium	mg/l	36	0.6	32	34	24.65 ± 16.78
10	Magnesium	mg/l	0.5	0.00	0.4	0.00	0.23 ± 0.26
11	Potassium	mg/l	12	3.00	10	9.5	8.63 ± 3.90
12	Manganese	mg/l	0.00	0.10	0.00	0.01	0.03 ± 0.05
13	Nitrate	mg/l	51	46	50	54	50.25 ± 3.30
14	TH	mg/l	0.31	20	0.41	44.7	16.36 ± 21.04
15	EC	$\mu S/cm$	105	100	1.05	94.9	75.24 ± 49.63
16	TC	Count/ml	435	205	200	402	310.5 ± 125.45

CL** = Colourless, DB**** = Dark brown.

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Table 7: Monthly Concentration of Water Parameters from Fatee River Sand Dam, Naka Road (S4).

S/No	Parameters	Units	Months				Mean ± SD
			Dec.	Jan.	Feb.	March	
1	Colour	Pt.co	CL**	CL	CL	CL	-
2	Odour	-	Odourless	Odourless	Odourless	Odourless	-
3	Temperature	˚C	25	23	20	27	23.75 ± 2.99
4	Turbidity	NTU	28	25	24	1.5	19.63 ± 12.20
5	TDS	mg/l	45	43	40	80	52 ± 18.78
6	pH	-	6.8	6.5	6.5	6.5	6.58 ± 0.15
7	Iron	mg/l	0.46	0.43	0.42	0.29	0.4 ± 0.08
8	Chloride	mg/l	0.69	0.66	0.65	0.23	0.56 ± 0.22
9	Calcium	mg/l	12	13	12	8	11.25 ± 2.22
10	Magnesium	mg/l	0.34	0.25	0.4	1.13	0.53 ± 0.40
11	Potassium	mg/l	5.2	4.2	10	3.6	5.75 ± 2.91
12	Manganese	mg/l	0.00	0.01	0.01	0.00	0.005 ± 0.006
13	Nitrate	mg/l	43	40	40	23	36.5 ± 9.11
14	TH	mg/l	1.71	1.68	1.65	1.53	1.64 ± 0.08
15	EC	$\mu S/cm$	165	1.42	1.42	150	79.46 ± 90.32
16	TC	Count/ml	243	240	122	150	188.75 ± 61.99

CL** = Colourless.

Table 8: Monthly Concentration of Water Parameters of Jamu Sand Dams (S5).

S/No	Parameters	Units	Months				Mean ± SD
			Dec.	Jan.	Feb.	March	
1	Colour	Pt.co	DB****	DB	DB	B***	-
2	Odour	-	Acceptable	Acceptable	Acceptable	Acceptable	-
3	Temperature	˚C	27	27	31	27	28 ± 2
4	Turbidity	NTU	237	195	221	207	215 ± 18.11
5	TDS	mg/l	257	142	204	136	220 ± 57.14
6	pH	-	6.8	6.5	6.5	6.7	6.63 ± 0.15
7	Iron	mg/l	0.87	0.73	0.68	0.78	0.77 ± 0.08
8	Chloride	mg/l	0.01	0.01	0.00	0.00	0.005 ± 0.006
9	Calcium	mg/l	35	33	32	30	32.50 ± 2.08
10	Magnesium	mg/l	0.012	0.01	0.01	0.00	0.008 ± 0.005
11	Potassium	mg/l	0.00	0.00	0.00	0.00	0 ± 0
12	Manganese	mg/l	0.00	0.01	0.10	0.00	0.03 ± 0.05
13	Nitrate	mg/l	42	41	43	48	43.5 ± 3.11
14	TH	mg/l	98	96	94	90	94.5 ± 3.42
15	EC	$\mu S/cm$	282	280	262	271	273.75 ± 9.18
16	TC	Count/ml	402	396	132	392	330.50 ± 132.40

B*** = Brown, DB**** = Dark brown.

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Table 9: Mean Concentrations and Compliance Rates of Parameters in Sand-dam Water Extracted via Scoop Holes.

			Mean ± SD for Sand Dam Sites					Reference standards		
S/ N	**Paramet ers**	**Units**	**S1**	**S2**	**S3**	**S4**	**S5**	**WHO***	**EU****	**NSDWQ*** **
1	Colour	Pt.co	-	-	-	-	-	Accepta	Accepta	Acceptable
2	Odour	-	-	-	-	-	-	ble	ble	Odourless
3	Temperat	˚C	26.75 ± 0.5	27.50 ±	26.58 ±	23.75 ± 2.99	28 ± 2	Odourle	Odourle	-
4	ure	NTU	26.50 ±	1.73	1.35	19.63 ± 12.20	215 ±	ss	ss	5
5	Turbidity	mg/l	2.99	117.05 ±	456.43 ±	52 ± 18.78	18.11	28	-	500
6	TDS	-	44.25 ±	66.77	365.68	6.58 ± 0.15	220 ±	1	Accepta	6.5 – 8.5
7	pH	mg/l	22.35	99.18 ±	488.68 ±	0.4 ± 0.08	57.14	1000	ble	0.3
8	Iron	mg/l	6.58 ± 0.13	68.51	431.36	0.56 ± 0.22	6.63 ± 0.15	6.5 – 8.5	-	250
9	Chloride	mg/l	0.35 ± 0.05	6.55 ± 0.21	6.53 ± 0.21	11.25 ± 2.22	0.77 ± 0.08	0.3	≥ 6.5 ≤	75
10	Calcium	mg/l	1.02 ± 0.55	0.67 ± 0.38	0.90 ± 0.21	0.53 ± 0.40	0.005 ±	250	9.5	20
11	Magnesiu	mg/l	12.06 ±	1.01 ± 1.20	28 ± 18.70	5.75 ± 2.91	0.006	200	0.2	-
12	m	mg/l	7.28	0.34 ± 0.37	24.65 ±	0.005 ± 0.006	32.50 ±	150	250	0.2
13	Potassiu	mg/l	2.64 ± 4.91	0 ± 0	16.78	36.5 ± 9.11	2.08	3000	-	50
14	m	mg/l	0.63 ± 0.49	2.95 ± 0.31	0.23 ± 0.26	1.64 ± 0.08	0.008 ±	0.1	125	-
15	Mangane	µS/cm	0.25 ± 0.50	0.03 ± 0.05	8.63 ± 3.90	79.46 ± 90.32	0.005	10	-	1000
16	se	Count/	28.75 ±	41 ± 10.74	0.03 ± 0.05	188.75 ±	0 ± 0	500	0.05	10
	Nitrate	ml	23.17	14.50 ±	50.25 ±	61.99	0.03 ± 0.05	2500	50	
	TH		26.75 ±	6.66	3.30		43.5 ± 3.11	0	100 –	
	EC		10.87	99.53 ±	16.36 ±		94.5 ± 3.42		500	
	TC		51.16 ±	4.17	21.04		273.75 ±		2500	
			86.30	151.75 ±	75.24 ±		9.18		0	
			123.75 ±	64.78	49.63		330.50 ±			
			10.54		310.5 ±		132.40			
					125.45					

KEY:

*Source: Daramola and Akindureni, 2017; **Source: EPA, 2012; Etim *et al.*, 2013.; ***Source: NSDWQ, 2007; Garba *et al.*, 2018

Total hardness varied from 0.31 – 98 mg/l with a mean ± SD value of 26.75 ± 10.87, 14.50 ± 6.66, 16.36 ± 21.04, 1.64 ± 0.08, and 94.5 ± 3.42 for the various five sand dam sites namely S1, S2, S3, S4, and S5 respectively (Table 9), the values were below the WHO, EU and NSDWQ standard values (Figure 4).

The Nitrate showed relative variations of 0.01 – 54 mg/l for the various month with a mean ± SD value of 28.75 ± 23.17, 41 ± 10.74, 50.25 ± 3.30, 36.5 ± 9.11, and 43.5 ± 3.11 for the five sand dam sites respectively (Table 9) and conformed reasonably with standard limits of WHO, EU and NSDWQ (Figure 5).

High levels of nitrate in dam reservoirs and lakes are indication that, there are significant run- off of waste discharges and artificial fertilizers from agricultural lands. Nitrate in

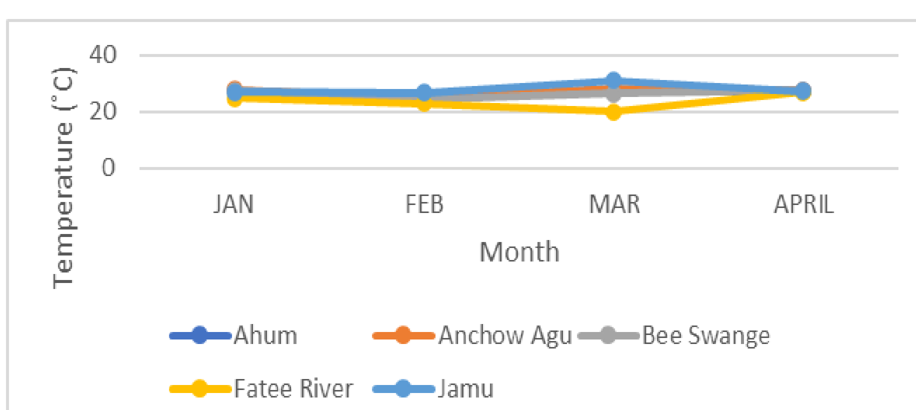

Figure 1: Temperature Variation in the Study Areas

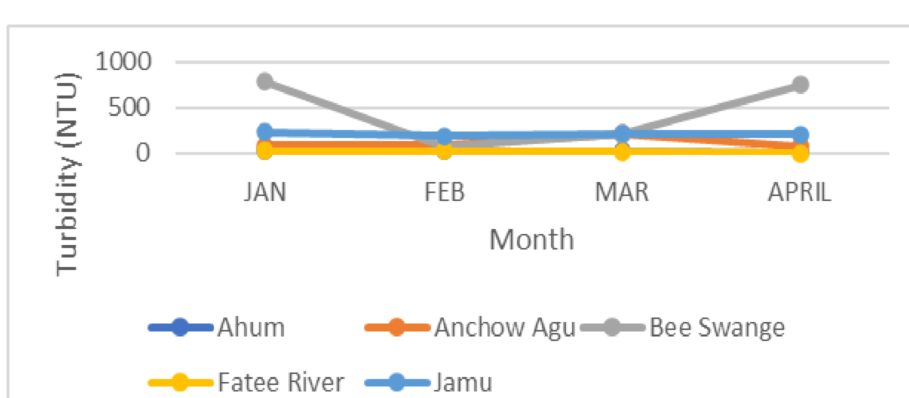

Figure 2: Turbidity Variation in the Study Areas

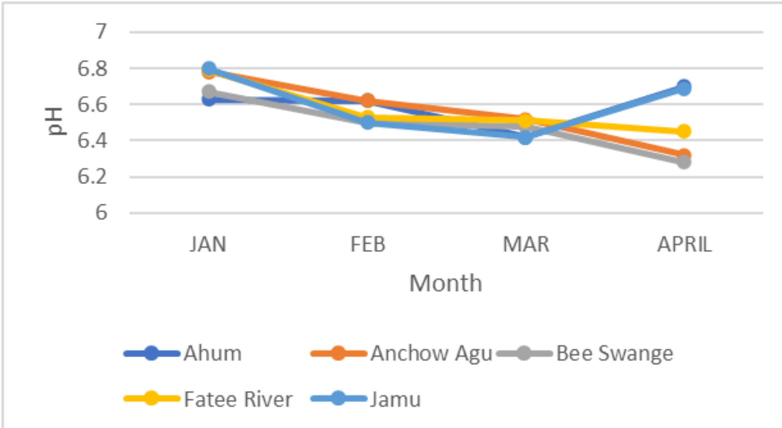

Figure 3: pH Variation in the Study Areas.

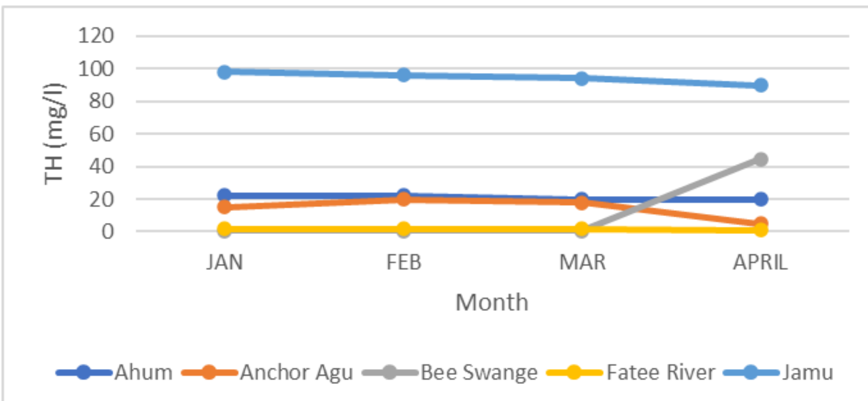

Figure 4: Total Hardness Variation in the Study Areas

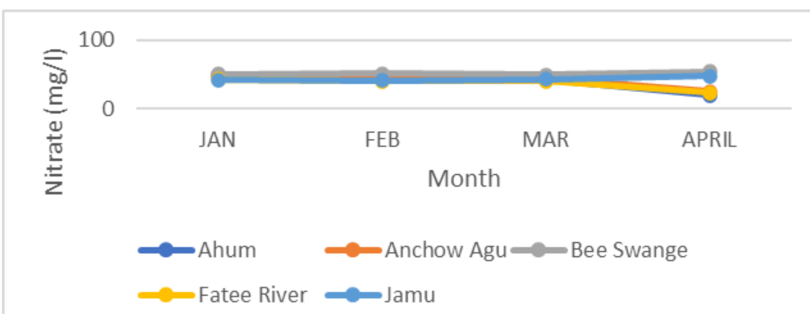

Figure 5: Nitrate Variation in the Study Areas

drinking water above threshold of 45 mg/l, which may give rise to a condition known as methemoglobinemia in infants and pregnant women (Onoja *et al*., 2017).

Electrical conductivity (EC) varied from 1.42 to 282µS/cm with the mean ± SD value of 51.16 ± 86.30, 99.53 ± 4.17, 75.24 ± 49.63, 79.46 ± 90.32, and 273.75 ± 9.18 for the five sand dam sites namely (Table 9). The values were below the WHO, EU and NSDWQ standard values. Low level of EC may be due to higher volume of the water in the sand dam and lower temperature which does not favour ionization (Ammara *et al*, 2020).

Total coliform varied from 72 – 435 Count/ml for the various months with a mean value of 123.75 ± 10.54, 151.75 ± 64.78, 310.5 ± 125.45, 188.75 ± 61.99, and 330.50 ± 132.40 for five sites respectively (Table 9). These values are far greater (Figure 6), than the standard limits of WHO, EU and NSWDQ which are 0, 0 and 10 respectively. This is an indication that all the five water sites are polluted with possible presence of pathogenic micro-organisms.The consumers are therefore at risk of infectious diseases that might be caused by the various pathogenic organisms (i.e. the actual disease-causing organisms) present in the contaminated sand dams. This is expected because almost all the seasonal rivers that form the

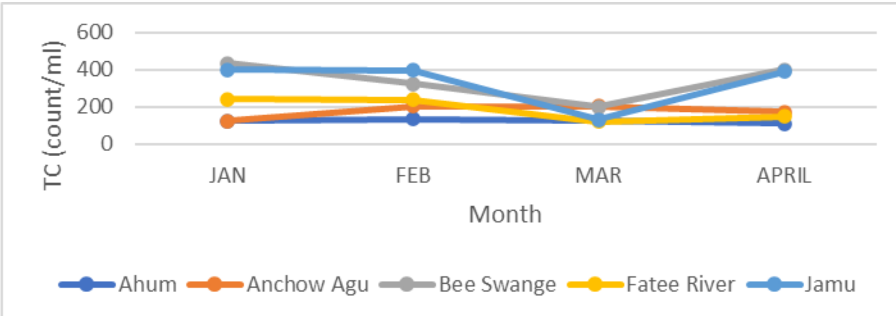

Figure 6: Total Coliform Variation in the Study Areas

riverbeds which equally give rise to sand dams do flow and overflow its banks from within and around the settlements of the inhabitants.

3.2.3 Metal elements concentrations in the water

Metals elements such as Iron (Fe), Chlorine (Cl), Calcium (Ca), Magnesium (Mg),Potassium (K),Manganese(Mn)were tested,(Table9).The presence of Iron,Chlorine,Calcium,Magnesium Potassium, Manganese varied from 0.29 to 1.01 mg/l; 0.01 to 39 mg/l, 0.04 to 36 mg/l, 0.22 to 10 mg/l, 0.20 to 12 mg/l, 0.001 to 1.0 mg/l with mean ± SD values of 0.35 ± 0.05, 0.67 ± 0.38, 0.90 ± 0.21, 0.4 ± 0.08, and 0.77 ± 0.08 for iron in the five sand dam sites (Table 9). Chlorine had a mean ± SD of 1.02 ± 0.55, 1.01 ± 1.20, 28 ± 18.70, 0.56 ± 0.22, and 0.005 ± 0.006 respectively. Calcium had a mean ± SD of 12.06 ± 7.28, 0.34 ± 0.37, 24.65 ± 16.78, 11.25 ± 2.22, and 32.50 ± 2.08. Magnesium had a mean ± SD of 2.64 ± 4.91, 0 ± 0, 0.23 ± 0.26, 0.53 ± 0.40, and 0.008 ± 0.005. Potassium had a mean ± SD of 0.63 ± 0.49, 2.95 ± 0.31, 8.63 ± 3.90, 5.75 ± 2.91, and 0 ± 0 . Manganese had a mean ± SD of 0.25 ± 0.50, 0.03 ± 0.05, 0.03 ± 0.05, 0.005 ± 0.006, and 0.03 ± 0.05 respectively,(Table 9).

Iron concentrations from all the sites were above and the recommended values of WHO, EU and NSDWQ (Table 9), while the manganese concentration was slightly higher in site(S1) (Figure 7 and 8). The main natural sources of Fe in groundwater are the dissolution of iron-bearing minerals like magnetite, pyrite, siderite, amphiboles, pyroxenes, olivine, biotite, glauconite and smectite, reduction of Fe-oxyhydroxides as hematite (Fe_2O_3) and goethite (FeO(OH)) and amorphous ($Fe(OH)_3$) present in sediments (Hiiob *et al.*, 2014).

Iron can cause severe problems in drinking water although there is normally no harmful effect on persons consuming waters with significant amounts of iron. The problems are primarily aesthetic, t a s t e , as the soluble (reduced) ferrous (Fe^{2+}) iron is oxidized in air to the insoluble ferric (Fe^{3+}) form, resulting in colour or turbidity. Laundry becomes stained if washed in water with excessive iron, (Bruce, 2010; NIH, 2019) and harmful to aquatic life(Nathan *et al.*, 2013). Excess Manganese might cause neurological disorder (WHO, 2020).

Chlorine, Calcium, Magnesium and Potassium were found to be below recommended values of WHO, EU and NSDWQ. Their presence in the waters might be from seepage of industrial wastes and percolation of water through iron-containing rocks nearby before flowing into the sand dam (Ayodele and Percy, 2011; Akinbile *et al.*, (2013).

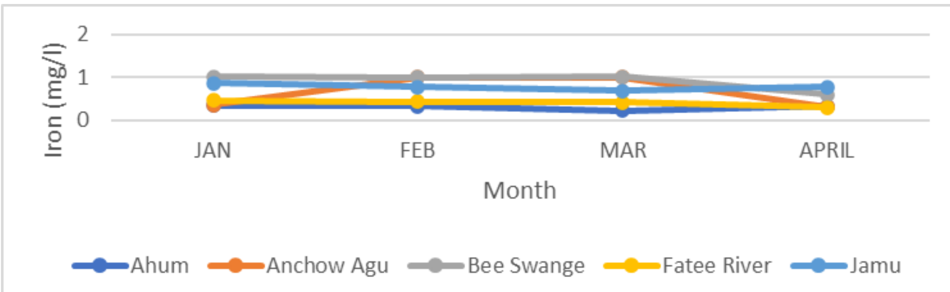

Figure 7: Iron Variation in the Study Areas

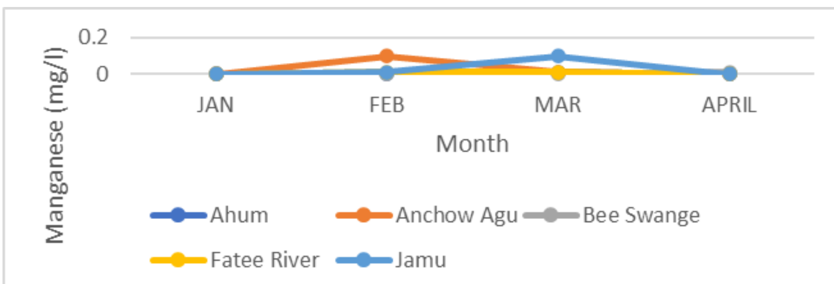

Figure 8: Manganese Variation in the Study Areas

3.3 Water Quality Index of the Sand Dams

After analyzing the required physiochemical parameters, water quality index was determined using the WQI.

The water quality index (WQI) for Bee Swange, Fatee river, Anchow Agu, Ahum and Jamu sand dams were calculated using the *WQI calculator by Oram (2014).* The result showed that the overall water quality index is 22.89 (Table 10). This WQI values falls under the rated standard of "very poor quality" and its unsuitable for drinking and fish culture((Bora and Goswami, 2017) (Table 11).

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Table I0: Water Quality Index Calculation and Result

Raw Data Entry

Dissolved Oxygen Saturation	E. Coliform #/100 mL	pH	BOD -5 mg/L	Delta Temp degrees C	Phosphate mg/L	Nitrate mg/L	Turbidity NTU	TS mg/L
-	-	6.57	-	26.52	-	40	116.92	-
	min. value entered = 1							

Q-Value Calculation

Dissolved Oxygen	Fecal Coliform	pH	BOD -5	Delta Temp	Phosphate	Nitrate	Turbidity	TS
50	2	75	2	16	2	18	5	20

Weighted Q-Value

Dissolved Oxygen	Fecal Coliform	pH	BOD -5	Delta Temp	Phosphate	Nitrate	Turbidity	TS
8.50	0.32	8.27	0.22	1.74	0.20	1.84	0.40	1.40

Overall Water Quality Index (score out of 100):	**22.89**
Water Quality Category:	**Very Bad**

Table 11: Water Quality Index (WQI) Range, Status and Possible Usage of the Water

WQI	Water Quality Status (WQS)	Possible usage
0 – 25	Unsuitable for drinking and fish culture	Proper treatment required before use
26 – 50	Very poor	Irrigation
51 – 75	Poor	Irrigation
76 – 100	Good	Drinking, irrigation and industrial
Above 100	Excellent	Drinking, irrigation and industrial

4. CONCLUSION

Sand dams were identified at various vicinities around Makurdi town. Dams' water were analyzed for drinking water suitability, some of the parameters (Turbidity, TC, Fe and Mn),were above the threshold, while other parameters (pH, Cl, Ca, Mg, K) were found to be within the threshold limit and the remaining parameters(TDS, Nitrate, TH, EC) were within the acceptable limits. The overall water quality index was found to be 22.89 which is rated as very poor quality.

The population of people that patronized the sand dams at the study sites out numbered the water yield from the dams, therefore, are exhausted and dried up within the middle of dry season, forcing the people to travel far distances searching for drinking water.
It is recommended that the sand dams water should be treated properly before use for drinking, irrigation and industrial purposes.
Sand dams should be constructed using modernized structures to increase water storage which will invariably provide and preserve enough clean water throughout the dry season for the people.

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