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Data Evaluation as a Guide in Water Treatment Process Selection

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Abstract: *Data analysis and evaluation form the basis of all engineering design. In order to come up with a cost effective design of a water treatment plant in small communities around Maiduguri, Borno State, the population as well as the surface water within the selected localities were evaluated and analyzed leading to a process selection which is expected to provide potable drinking water that satisfies the requirement of WHO (world Health Organization) standard.*

Key words: *Data evaluation, water treatment, process selection*

I. Introduction

Absolutely pure water is rarely found in existence in nature, so there has always been a demand for pure portable water [3].

Most waters have to be purified before they can be used for portable purposes. Raw water is so infinitely variable in quality, that there is no fixed starting point to the treatment process, and within much narrower limits, there is no fixed starting point to the treatment process, and within much narrower limits, there is no rigidly fixed finishing point either.

There is virtually no water that is impossible to purify into potable standards. Accordingly it may be free from disease-producing organisms and poisonous or physiological undesirable substances[1].

The source of raw water determines its inherent quality, the quality of which is difficult to foresee, hence there is the need to collect samples of the raw water for a certain period of time and carry out some tests to ascertain the characteristic purities of the raw water and the relative quantity of each impurity.

Naturally occurring water can generally be classified as; groundwater, or surface water. Each has its own characteristic, but in general, ground water is the purest form of water available, and may not require much treatment compared to its counterpart (surface water).

Basic Needs

i. Due to health hazards experienced in different parts of the country, especially in rural communities; where the only supply of water is from a river source, free flowing stream or ponds which are not kept in good sanitary conditions, resulting in high epidemic rates such as cholera, typhoid guinea worm diseases etc.
ii. The needs to reduce the nation's high health bills due to epidemics, and other water borne diseases.
iii. The need to improve on the water supply system in rural communities.

II. History of Water Treatment

The History of water-quality improvement dates back to the history of man, when he realised that allowing water to stay for some hours or days improves its clarity. This is due to the gravitational forces acting on the suspended particles in water which causes them (naturally) to settle down at the bottom of the container to which they are kept. This simple art of allowing water to stay for some time in the bid to improve its clarity is called sedimentation. [5]

The use of sand as a form of filter dates back to the ninth century, where it was used as a form of deep-bed filter. Different layers of sands from the coarsest to the finest were arranged so that the raw water passes from the coarsest to the finest sand by means of gravity, thereby trapping the impurities, which are in the form of suspended solid particles along its way to the finest sand. [5]

The use of chemicals such as coagulants e.g. aluminum sulphate was used in conjunction with rapid sand filters in the late 19[tn] century. The use of these chemical form a flocculent precipitate which traps suspended matter, and aids its removal by other chemicals like lime, iron sulphate were also used. [5]

Flocculation as a means of further improvement in the quality of water is a relatively new invention, which emergedin about the 19[th] century. This is the process whereby the water purification stage of coagulation is further enhanced by the rotating members to form large floc which become heavy and easy to settle in the bottom of the tank. [5]

The disinfection of water as the final process for assuring its safety for the consumer was not practiced until the first decade of the 20th century. The earliest form of chemicals used for this disinfection was bleaching powder, hypo-chlorides, and later chlorine gas, which were found to be successful in earlier water works. [5]

The first successful water treatment plant for domestic use was in New York (United States) in 1871, which was based on the slow sand filtration process, in addition to other purification techniques [4]. The first successfully use of chemical coagulants was that in 1884, also in the United States, which used metal salts, principal1y those of iron and aluminum [4].

Later developments of treatment plants both for domestic and industrial usage was enhanced by modern techniques, which dissolved new purification methods based on known scientific facts, and also the modification of previous techniques, by enhancing or combining separate processes together.

III. Quality of Water

The quality of water is defined in terms of its associated impurities. This gives a true picture of the type of impurities and their relative amounts, which vary with time, season of the year etc.

The quality of the raw water can be considered as the main design criteria, as it gives an idea of the treatment required for each impurity.

Thus, the design criteria or parameters used in the treatment of water based on its quality are [4].

i. Determine the class under which the impurity falls.
ii. Ascertain the TDS (Total dissolved salts) of the raw water.
iii. Decide on the degree of end-product purity.

From these criteria, it is possible to decide upon purification process/processes to be employed only rarely will a single method be adequate [4].

Usually the aim of this quality assessment is to compare the raw water quality with that of approved standards of potable usually these are standards set by public departments or those adopted from WHOs standard (World Health organization).

IV. Standards for Potable Water

There are no hard and fast rules as to the acceptable quality for potable supplies, but certain guidelines have been laid down. If these are not exceeded, no action is necessary, because the cost of providing and operating the treatment plant is appreciable and may represent an unwanted cost [1].

The World Health Organization has developed standards for developing nations which are as shown in appendix 1.0. This gives desirable concentrations, and also the maximum permissible concentration for each type of impurity [1].

V. Data Analysis and Process Selection

The essence of taking relevant data on the type, quality and quantity of the water in question is necessary, as it form the backbone of the design. Such information include, vertical head, distance from water source to outlet, purpose of water, altitude above sea level, pumping cycle, quality of water, legal right of water, power available and source of water. It is after a thorough analysis and consideration of the above key points or key factors that go along in determining the process or group of processes necessary for the economic treatment of raw water.

Data on Population Figures of Some Villages in Maiduguri Area (1963 Census)

Due to the unavailability of the 1991 CENSUS result for individual locality of Maiduguri area, that of 1963 CENSUS projected was used as a basis for the design. Though the figure as reported by the 1991 CENSUS of the nation's population is less than that of 1963, a sort of correction has to be made by the use of the dynamic nature of this water treatment plant capacity.

Table 1: Some statistical report of population figures of some villages in Maiduguri area projected from 1963 census.*

YEAR	MAFA	AUNO	DALRI	KONDUGA
1963	3,888	5,825	6,460	6,467
1991	7,762	11,629	12,897	9,840
1992	7,956	11,929	13,219	10,086
1993	8,155	12,218	13,555	10,338
1994	8,359	12,513	13,889	10,849
1995	8,568	13,157	14,236	11,391
1996	8,702	13,486	14,956	11,160
1997	8,801	13,823	15,350	12,559
1998	9,001	14,001	15,430	12,923
1999	9,254	14,169	15,714	13,186
2000	9,694	14,525	16,107	13,846

*National Population Commission Maiduguri Branch

VI. Data Analysis

From the data above, it is possible for one to have a rough idea of the number of people to be considered and hence the amount of water expected to be consumed by them, which is one of five key design features. Let the life span of the design be taken to be 15 years. This means that an estimate of the population in 15 years to come is needed starting from 1992. (i.e. to the year 2007). Thus we need to further project these figures to the year 2007. Since the design is not specified to a particular locality, but taken to a common locality, which happen to share some common characteristic, an average of the population is used in the form of arithmetic mean to serve as a representative of the group.

Arithmetic mean (A.M) $= \frac{X1+X2+X3+\cdots Xn}{N}$

$$= \sum_{i=1}^{N} X1/N$$

For 1963 census figure,

A.M = Population of $\frac{(Mafa+Auno+Konduga+Dalri}{4}$

$$= \frac{3{,}888+5{,}825+6{,}460+6{,}467}{4}$$

$$= \frac{2{,}2640}{4}$$

A.m. = 5,660

Hence the mean population in 1963 was 5,660.

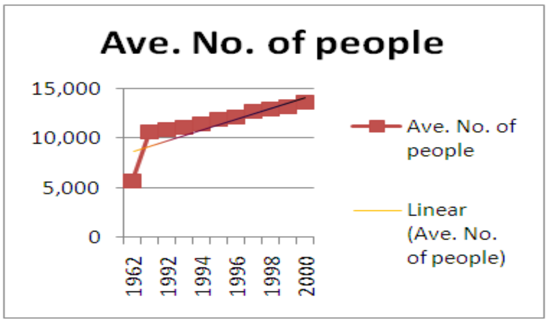
Thus,

TABLE 2: Mean Population Projection

Year	Ave. No. of people
1963	5,660
1991	10,532
1992	10,798
1993	11,067
1994	11,403
1995	11,838
1996	12,076
1997	12,633
1998	12,839
1999	13,081
2000	13,543

To project to the year 2007, a graph of the years versus population figure needs to be drawn, and projected to that year, assuming a linear relationship between the two variables Fig. 1.

Fig 1: Graph of Population figure Vs Time



From this graph, the expected or approximate population at any instant of time may be determined by projecting to that year. Assuming all conditions remains unchanged. Thus since the design life span is to be 15 years, (i.e. up to the year 2007). Periodical adjustment need to be done say over 5 year intervals to cater for changes such as increased demand due to population increase. Thus for now, the population expected in the next 5 years is 12,400 (i.e. 1997), from the graph fig 1.

Thus, the population or number of heads to be considered in the first phase is 12,400. An approximated figured of 13,000 is to be used (i.e. an increase of 600) this is to serve some domestic animals who will also make use of the water.

The average rural water consumption is 20 liters/day. [7]. Thus, the water consumption per day is given by 13,000 people at 20 liters/head/day = 260,000 liters/day

Thus the daily water consumption is 260,000liters/day (56,968 Gals).

VII. Chemical Analysis of Water

The chemical analysis of the raw water was carried out and the results obtained are as indicated in tables 3 – 7

TABLE 3: Analysis for October 1991

PROPERTY	VALUE
Temperature at site	21.00°C
Temperature in lab	23.00°C
PH	7.80
Turbidity	23.00NTU
Specific conductance	133μmHos/cm
Colour	-
Dissolved oxygen	-
Bicarbonate ($CaCo_3$)	55.00 mg/1
Ammonia Nitrogen (N)	0.10 mg/1
Fluoride (F)	0.80 mg/1
Chloride (Cl_2)	11.00 mg/1
Sulphate (SO_4^{2})	-
Hardness	42.00 mg/1
Phosphate (PO_4)	16.70 mg/1
Sodium (Na)	8.50 mg/1
Potassium (K)	6.60 mg/1
Boron (B)	
Carbon dioxide (CO_2)	
Magnesium (Mg)	
Calcium (Ca)	

TABLE 4: Analysis for November 1991

PROPERTY	VALUE
Temperature at site	31.00°C
Temperature in lab	33.00°C
PH	6.80
Turbidity	-
Specific conductance	130μmHos/cm
Colour	-
Dissolved oxygen	-
Bicarbonate ($CaCo_3$)	44.00 mg/1
Ammonia Nitrogen (N)	-
Fluoride (F)	-
Chloride (Cl_2)	13.00 mg/1
Sulphate (SO_4^{2})	-
Hardness	20.00 mg/1
Phosphate (PO_4)	-
Sodium (Na)	6.00 mg/1
Potassium (K)	5.00 mg/1
Boron (B)	0.30 mg/1
Carbon dioxide (CO_2)	-
Magnesium (Mg)	14.00 mg/1
Calcium (Ca)	-

TABLE 5: Analysis for December 1991

PROPERTY	VALUE
Temperature at site	21.00°C
Temperature in lab	27.00°C
PH	7.55
Turbidity	-
Specific conductance	97.00μmHos/cm
Colour	-
Dissolved oxygen	-
Bicarbonate ($CaCo_3$)	44.00 mg/1
Ammonia Nitrogen (N)	-
Fluoride (F)	-
Chloride (Cl_2)	8.00 mg/1
Sulphate (SO_4^{2})	3.00 mg/1
Hardness	26.30 mg/1
Phosphate (PO_4)	-
Sodium (Na)	-
Potassium (K)	-
Boron (B)	-
Carbon dioxide (CO_2)	38.00 mg/1
Magnesium (Mg)	8.00 mg/1
Calcium (Ca)	18.00 mg/1

TABLE 6: Analysis for January 1992

PROPERTY	VALUE
Temperature at site	22.30°C
Temperature in lab	25.00°C
PH	7.2
Turbidity	12.15 NTU
Specific conductance	125.00μmHos/cm
Colour	80.60 Mg/1
Dissolved oxygen	8.10
Bicarbonate ($CaCo_3$)	56.00 mg/1
Ammonia Nitrogen (N)	0.1
Fluoride (F)	0.5 mg/1
Chloride (Cl_2)	12.00 mg/1
Sulphate (SO_4^{2})	3.50 mg/1
Hardness	40.00 mg/1
Phosphate (PO_4)	0.90 mg/1
Sodium (Na)	7.80 mg/1
Potassium (K)	6.80 mg/1
Boron (B)	0.30 mg/1
Carbon dioxide (CO_2)	-
Magnesium (Mg)	-
Calcium (Ca)	-

TABLE 7: Analysis for February 1992

PROPERTY	VALUE
Temperature at site	21.00°C
Temperature in lab	23.00°C
PH	7.80
Turbidity	23.00 NTU
Specific conductance	133.00μmHos/cm
Colour	135.00 Mg/1
Dissolved oxygen	-
Bicarbonate ($CaCo_3$)	-
Ammonia Nitrogen (N)	0.1 mg/1
Fluoride (F)	0.80 mg/1
Chloride (Cl_2)	11.00 mg/1
Sulphate (SO_4^{2})	-
Hardness	42.00 mg/1
Phosphate (PO_4)	16.70 mg/1
Sodium (Na)	8.50 mg/1
Potassium (K)	6.60 mg/1
Boron (B)	-
Carbon dioxide (CO_2)	-
Magnesium (Mg)	-
Calcium (Ca)	-

Generally, there is no end to the type of treatment that can be carried out on water which depends mainly on the purpose to which the water is to be used (i.e. either for domestic or industrial). Thus a compromise between economy and necessities is made. Hence, from the data obtained on the Alau water which is the basis of design, the actual quality of the water is taken to be that obtained from the worst possible case as detected by the chemical analyst. This is due to the fact that the samples should have been taken over a 12 month period or more to get the true nature of the impurities been handled. Thus the respective values of the worst conditions of these impurities are as stated in table 8. These values are compared with those of WHO (World Health Organization). Appendix 1.0 since there is no set standard in Nigeria.

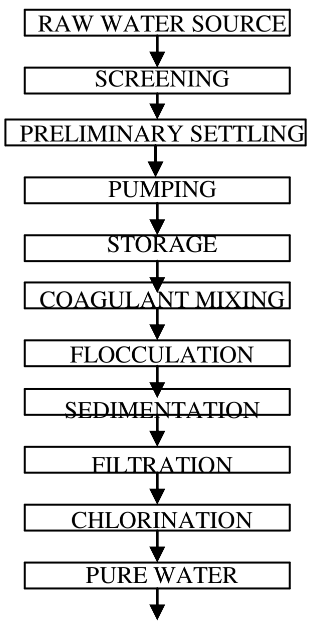
TABLE 8: Worst case values of water analysis

PROPERTY	VALUE
Temperature at site	31.00°C
Temperature in lab	33.00°C
PH	7.80
Turbidity	23.00 NTU
Specific conductance	133.00μmHos/cm
Colour	135.00 Mg/1
Dissolved oxygen	8.10 mg/1
Bicarbonate ($CaCo_3$)	56.00 mg/1
Ammonia Nitrogen (N)	0.10 mg/1
Fluoride (F)	0.80 mg/1
Chloride (Cl_2)	13.00 mg/1
Sulphate (SO_4^{2})	3.50 mg/1
Hardness	42.00 mg/1
Phosphate (PO_4)	16.70 mg/1
Sodium (Na)	8.50 mg/1
Potassium (K)	6.80 mg/1
Boron (B)	0.30 mg/1
Carbon dioxide (CO_2)	38.00 mg/1
Magnesium (Mg)	14.00 mg/1
Calcium (Ca)	18.0 g/1

Process Selection

The choice of the treatment process to be adopted depends on the impurities to be handled among others as previously discussed in VII. Thus, referring to Appendix 1.0, also on some design discretions a possible treatment process is given in the flow diagram below.

Fig 2: Process Selection Diagram



VIII. Conclusion

The need for proper data analysis most often depend on the data itself, there should be more appropriate and reliable means of water quality assessments in this country which has very poor data collection and management techniques. This may to a great extent alter many assumptions taken for a design; as such wide margins of error which were taken (to be on the safe side) for this design could have been avoided. The data on population census for individual localities should also be well documented for purposes such as these.

There should also be a standard for potable drinking water in this country which unfortunately there isn't. This data on potable water standards should be taken by well qualified personnel, so that a standard should be set for this country rather than depend on international standards, which may not really reflect the situation in this country.

References

[1]. Smsrthurst G.: Basic Water Treatment 1979; Thomas Telford Ltd, London.
[2]. M. Fair, Gordon/C. Geyer, John/A. Okun, Daniel. Water and Waste water Engineering Vol.1, 1968, John Willey and Sons Inc.
[3]. James G. V.: Water Treatment; 4th Edition, 1971, Technical Press.
[4]. Walter Lorch: Handbook of water purification, 1981, London; New York: McGraw-Hill (UK),
[5]. M. Fair, Gordon/C. Geyer, John/A. Okun, Daniel; Water and Waste water Engineer Vol. 2,1968, John Willey and Sons Inc.
[6]. Mogarr, F: Water and Waste water utilization in hot climate
[7]. Dunn, P.D.: Appropriate Technology;1978, McMillian Press Ltd
[8]. 8.Ernest F Branter, Horace W King, James E Lindell, C Y Wei 1996, Handbook of Hydraulics, McGraw-Hill, a Division of the McGraw-Hill Companies, Inc.

APPENDIX 1.0: RECOMMENDED TREATMENT

Treatment system	Bacteria, amoebas	Guinea-worm	Cercaria	Fe, Mn	Fluoride	Arsenic	Salts	Odour, taste	Organic matter	Turbidity
Straining through fine cloth Consists in pouring raw water through a piece of fine, clean, cotton cloth to remove some of the suspended solids.	–b	©©©	—	—	—	—	—	—	©	©
Aeration Oxidizes iron (Fe) and manganese (Mn). Good aeration of the water is also important for slow, sand filtration to be effective, especially if there is not enough oxygen in the surface water. Water can easily be aerated by shaking it in a vessel, or by allowing it to trickle through perforated trays containing small stones.				©©©				©©	©	
Storage/pre-settlement Storing water for only one day can eliminate some bacteria, but it should be stored for 48 hours to eliminate cercaria (snail larvae). The longer the water is stored, the more the suspended solids and pathogens will settle to the bottom of the container. The top water can then be used after sedimentation.	©		©©©	©				©	©	©©
Coagulation, flocculation and settlement In coagulation, a liquid coagulant, such as aluminium sulfate, is added to the water to attract suspended particles. The water is then gently stirred to allow the particles to come together and form larger particles (flocculation), which can then be removed by sedimentation, settlement or filtration. The amount of coagulant needed will depend on the nature of the contaminating chemical compounds and solids.	©		©	©	©©©	©©©		©	©	©©

Slow sand filtration Water passes slowly downwards through a bed of fine sand at a steady rate. The water should not be too turbid; otherwise the filter will get clogged. Pathogens are naturally removed in the top layer where a biological film builds up. A potential problem is that some households do not use this technology effectively and the water can remain contaminated.	©©©	©©©	©©©	©©		©©		©©	©	©©©
Rapid sand filtration The sand used is coarser than in slow sand filtration and the flow rate is higher. The method is used to remove suspended solids and is effective after the water has been cleared with coagulation/flocculation. There is no build-up of biological film, hence the water will still need to be disinfected. It is easier to remove trapped debris from up flow sand filters, compared to filters in which the water flows downwards.	©	©©	©	©©				©	©	©©
Charcoal filter Granular charcoal (or granulated activated carbon) can be used in filtration and is effective in improving the taste, odours and colour of the water. However, it should be replaced regularly, because bacteria can breed in it.		©©	©©	©				©©©		©
Ceramic filter The filter is a porous, unglazed ceramic cylinder and impurities are deposited on its surface. Filters with very small pores can remove most pathogens. Open, porous ceramic jars can also be used. The ceramic filter method can only be used with fairly clear water.	©©©	©©©	©©©					©©	©©	©©©
Solar disinfection Ultraviolet radiation from the sun will destroy most pathogens, and increasing the temperature of the water enhances the effectiveness of the radiation. In tropical areas, most pathogens can be killed by exposing the contaminated water to sun for five hours, centered around midday. An easy way to do this, is to expose (half-blackened) clear glass/ plastic bottles of water to the sun. Shaking the bottle before irradiation increases the effectiveness of the treatment. The water must be clear for this treatment to be effective.	©©©	©©	©©							