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Comparative Analysis and Treatment of Well Water in Ebonyi State Nigeria

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Abstract

This project is concerned with comparative analysis and treatment of well waters in Ebonyi state, Nigeria. The well water samples for this analysis were obtained from the thirteen local government areas in the state and were analyzed for physco-chemical and microbiological parameters such as odour, pH, electrical conductivity, total hardness, magnesium, calcium ion, sulphate, nitrates, chemical oxygen demand (COD), turbidity, total coliform, Escherichia coli, faecal streptococci and plate count. The result of the experimental analysis using Response Surface Methodology (RSM) design called central composite design (CCD) showed that the chemical, physical and microbiological parameters are within the permissible limits of the NSDWQ/WHO except for nitrates, magnesium, turbidity, total coliform , Escherichia coli, plate count and faecal streptococci with values of 18.30 mg/, 7.05mg/l, 6.48 NTU, 611.00 cfu/ml, 6.92cfu/100ml, 2.62, and 141.23 cfu/100ml whereas the acceptable values by NSDWQ/WHO are 50.00/10.00mg/l, 0.20/150mg/l, 5.00NTU, 10.00/0cfu/ml, 0/0cfu/100ml, 0/0, 0/0cfu/100ml. Also, form the results of the analysis of the well water samples from Abakaliki, Afikpo North, Ezza south and Izzi local government areas contain iron content as high as 400 mg/l, 440 mg/l, 400 mg/l, and 400mg/l which are above the acceptable range of 300mg/l by NSDWQ/WHO). Therefore, from the results obtained the standard of well waters in Ebonyi state in terms of chemical, physical and microbiological data parameters are well below the required standard of NSDWQ and WHO, but can successfully be treated by adsorption method and annihilation of the microbes.

Keywords: *Well Water, Treatment, chemical, microbiological and physical Analysis*

1. Introduction

Generally water from aquifers is already of high quality because it has been filtered through many layers of chalk or sand and needs only disinfection with chlorine. But water from rivers and reservoirs contains a range of substances which need to be removed through several processes. Water is considered as one of the body nutrients, although it yields no calories yet it enters into the structural composition of cells and is an essential component of diet. It is common belief is that untreated well water generally is safe for consummative use [1].

In Ebonyi State, water is available in great quantities but contains a range of substances resulting to portable water being scarce. The use of well water in Ebonyi State is of the high demand but little attention is given to the purity of the water before consumption. Water well is obtained from excavations of holes underground in order to obtain water reservoirs. A greater number of Ebonyi residences depend on ground water and primarily well waters for their daily activities and consumptions. Although, about 24 million people in the world rely on private or individual water systems as their source of drinking water supply [2]

The existence and dangers of pathogenic microbes in surface water supplies like ponds, streams and rivers have been recognized for more than a century. Ground water as well as spring and wells were generally long thought to be naturally protected against contamination by pathogenic microbes. This justifies that protection that was attached to the natural filtration and neutralizing properties of sub-surface soil and geologic strata [2]. However, unsanitary disposal of refuse and garbage, increased use of agricultural pesticides and fertilizers, industrial operation, use of pit latrines and problems with septic tank systems constitute major anthropogenic activities causing pollution in water sources like wells [1].

Water is a very good solvent; and well water is not an exception which dissolves some toxic and hazardous substances posing many public health risks through dinking the water which is the major purpose the well water serves in Ebonyi state. There are many physicochemical parameters of interest in water quality assessments for human consumption. Some of the physiochemical parameters include temperature, pH, turbidity, salinity, odour, colour, taste and electrical conductivity. Others parameters include those that are chemically analysis of contaminated water may indicate qualities comprising magnesium hardness, calcium hardness, total hardness, nitrates, phosphates, certain trace elements; lead, arsenic, cadmium, manganese, sodium, total alkalinity, sulphates, chlorides, iron. The bacteriological analyzed parameters may include plate count, total coli-form and E-coli [3].

In Ebonyi state, the most common and wide spread health risk associated with drinking water was *Dracunculiasis*. Other pathogenesis transmitted by water in the state include typhoid, cholera, gastroenteritis, urinary tract infections, wound and burn infections, meningitis especially in neonates, diarrhea, dysentery, septicemia, pneumonia, respiratory tract infections, inflammations of lungs, ear and eye infections, enteritis, nosocomial infections, bacteraemia etc. Ruiz and Hopkins maintained that Dracunculiasis is caused by the nematode known as *Dracunculus medinensis* [3].

Discoloration of well waters may arise from the dissolution of iron (red) or copper (blue) in drawing pipes which can be enhanced by bacteriological processes. Microbiological action can also produce “red water” resulting from the oxidation of iron (II) to iron (III) by iron “bacteria”. Similarly, black discoloration may result from the action of bacteria capable of oxidizing dissolved manganese to give insoluble forms. Furthermore, colour-producing organic substances can react with chlorine to produce undesirable levels of chlorination by products [4]. The unpleasant odours and flavours in drinking water are a constant concern to consumers. The organoleptic properties of drinking water can be naturally induced or man-made [5].There are substantial grounds to support the possibility that unfamiliar drinking water odours might reveal the presence of substances, which pose a potential health risk [6].

Water serves a lot of industrial and domestic purposes. Industrially, water is used in quenching organic reactions, removing inorganic salts, hydropower generation, cooling of engines, extinguishing fire, etc and in domestic use for drinking, washing, bathing, cooking, building, etc. Whichever case, the determination of the physical, chemical and microbiological quality of water is indeed necessary as to ensure water safety. Water laboratory is a useful place for the monitoring and analysis of water. This is achieved by isolation and identification of the mineral constituents and pathogens present in the water under investigation. So many scholars have investigated the water quality and some of their studies are reviewed.

Water borne diseases claim a lot of lives every year in Ebonyi State but the water source responsible for such is not yet known. Originally, the sources of water supply in the Ebonyi state are rain, river/stream and pond water. Because of the consummative use of river water, Ebonyi state drew its name from a big river (Ebonyi River) which passes through the state. These water sources supply waters which were consumed without purification. The result of the consumption is the number of cases of water borne diseases was on increase. People of Ebonyi state resort to digging of wells which is the second class source of water supply in the state yet, people contact water borne diseases. The health effect of drinking contaminated and polluted water in Ebonyi state is devastating. The health cost of drinking contaminated water with some borne diseases is very expensive and in some cases may affect new born babies and children. This is a major contributor to the abysmal high infant mortality rate in Ebonyi state. “Guinea worm and *Onchocerchiasis* (River blindness) are endemic water –borne diseases associated with the state for a long time now. Just mention Ebonyi state water, a visitor completes it with the term guinea worm. Other major water borne diseases which the people have been suffering are cholera, amoebiasis, crytosporidiosis, cyclosporiasis, taeniasis, E. coli infection, typhoid fever, poliomyelitis, SARS, dysentery, leptospirosis, salnonellosis etc. all these have jeopardized the lives of people of the state in one way or the other.

The most worrisome effect of drinking water in Ebonyi state being the socio-economic impact of the transmitted water borne diseases. The water borne diseases have a significant impact on the economy of the state. People who are infected by the water borne diseases are usually confronted with related disabilities and huge financial burden. The financial burden is caused mostly by costs of medical treatment, transport, special food to maintain their health, and these challenges may cause loss of man power. Most families sell their valuable property like land, bicycle, motorcycle, cars, domestic animals, houses and times give out their underage daughters in marriage in order to pay for treatment. Most of the indigenes who are not literates spend their money in native doctors, soothsayers, shrines but their health problems may not be solved after waste their money and may still die. The quality of water in Ebonyi state has made some visitors to the state not feeling free to drink water on their visit to the state. Although, some visitors make adequate arrangement for their drinking water, only few visitors to the state consume water from Ebonyi state due the associated health risk. The above stated problems are the motivation for this research work on comparative analysis and treatment of well waters in Ebonyi state, Nigeria.

2. Purpose of the Study

The main purpose of this study is comparative analysis and treatment of well waters in Ebonyi State for the following reasons:

1. To monitor the physico-chemical and bacteriological quality of well waters in Ebonyi state.
2. To compare all examined well water quality parameters with WHO water quality standards and guidelines or Nigerian Standards for Drinking Water Quality (NSDWQ) index range.
3. To explore the well waters in the 13 local government areas in Ebonyi state Nigeria and compare the result with the health impact of the parameters.
4. To reduce any parameter above NSDWQ to a normal level.

2.1 Study Area

The study area of this project is the Ebonyi State Nigeria within the thirteen Local Government Area and have a land mass of approximately 5,932 sq.km and lies in approximately 7˚ 3´ N longitudes 5˚ 4´E and 6˚ 45´. It is bounded in the East by Cross River state, in the North by Benue State, in the West by Enugu State and in South by Abia State. According to the 2006 Nigeria census data, the state has a population of about 2,176,947 people.

3. Materials, Methods and Experimental Design

3.1 Sample Analysis and Treatment

A. The following parameters were determined from the analyzed samples: pH, turbidity, total dissolved solids, total suspended solids, iron, sulphates, chlorides, nitrates, Phosphates, conductivity, total hardness, calcium, magnesium, carbonates, bicarbonates, BOD, COD, of most probable number (MPN) of Coli Form , most probable number (MPN) of E-Coli and guinea worm copepods.

B. The optimum conditions for the reduction of iron content in the affected samples to NSDWQ limit.

Determination of the parameters in A above was done with mainly metric instruments like spectrophotometer, multi-parameter Hanna Bench Photometer, Turbidity meter, pH meter and thermometer.

3.2 Methods

In determining the optimum conditions for the reduction of iron content, the major material used is the clay obtained from 'Ngwulegwu' town in Ohaozara local government area of Ebonyi state. After removing the contaminants, the sample was ground and dried. In characterizing the clay, standard methods were used to determine the physical parameters while Atomic Adsorption Spectrophotometer (model 2010) was used to determine the oxides present in the digested samples.

The purified clay was activated an acid following the process of grinding, sieving using 180µm sieve size, treatment with 1.5M H_2SO_4 at acid to clay ratio of 2:1, heating at a temperature of 90^0C for 3 hours in a round bottom flask with reflux. Filtering and washing when activation is complete. Drying, sieving and storing the sample.

3.3 Experimental Design

The experimental design used for this study is Response Surface Methodology (RSM) design called central composite design (CCD). This CCD methodology was used for the optimization of iron removal conditions, the factors studied were adsorbate volume, adsorbent dosage and pH. The CCD was used to study the individual and synergistic effects of the three factors toward the response removal efficiency (%). The CCD is made of 3 components; the axial runs, factorial runs and centre runs. This gives the twenty experiments needed for the design. The factors and levels for the CCD are shown the tables 1. The experimental runs were randomized to minimize the effects of unexpected variability in the observed response. The response was used to develop a model that correlated the response to the process variables using second degree polynomial equation given below.

$Y = \beta_0 + \sum \beta_i X_i + \sum \beta_{ii} X_{ij} + \sum \beta_{il} X_i X_j + \epsilon$ ………….. (1)

Where Y is the predicted response variable, β_0 is constant coefficient, β_i is ith linear coefficient of the input variable X_i, β_{ii} is the ith quadratic coefficient of the input variable $X_{i.}$ β_{ij} is the different interaction coefficients between the input variables X_i and X_{ji} and ϵ is the error of the model. Table 1 shows the design matrix while Table 2 shows the ANOVA for response Surface Quadratic Model.

Table 1: Design Matrix

Std Order	***Run Order***	Adsorbent Dosage (g)	***PH***	Adsorbate Vol (mls)	
9	1	0.25	6.00	150.0	50.7
10	2	1.25	6.00	150.0	78.5
1	3	0.50	4.00	100.0	55.2
15	4	0.75	6.00	150.0	60.7
18	5	0.75	6.00	150.0	62

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Table 1: Design Matrix Continued

Std Order	***Run Order***	Adsorbent Dosage (g)	***PH***	Adsorbate Vol (mls)	
17	6	0.50	8.00	200.0	44
12	7	0.75	6.00	150.0	61.3
14	8	0.75	10.00	150.0	58.9
6	9	0.75	2.00	150.0	40
4	10	0.75	6.00	250.0	41
6	11	1.0	4.00	200.0	45.3
4	12	1.0	8.00	100.0	72.2
20	13	0.75	6.00	150.0	65.8
16	14	0.75	6.00	150.0	66.2
3	15	0.50	8.00	100.0	62.8
19	16	0.75	6.00	150.0	60.9
5	17	0.50	4.00	200.0	38.7
13	18	0.75	6.00	50.0	81.2
8	19	1.0	8.00	200.0	64.3
2	20	1.0	4.00	100.0	70.8

Table 2: ANOVA for response Surface Quadratic Model

Source Prob>	***Sum of squares***	df	***Mean Square***	F Val	P-val
Model	2762.95	4	690.74	58.16	< 0.0001
A-Adsorbent	722.27	1	722.27	60.82	< 0.0001
B-pH	315.95	1	315.95	26.61	0.0001
C-Adsorbate	1389.43	1	1389.43	117.00	< 0.0001
B^2	335.30	1	335.30	28.23	< 0.0001
Residual	178.13	15	11.88		
Lack of fit	146.66	10	14.67	2.33	0.1815
Pure Error	31.47	5	6.29		
Cor Total	2941.08	19			

The Model F-value of 58.16 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise.
Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case A, B, C, B2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.
The "Lack of Fit F-value" of 2.33 implies the Lack of Fit is not significant relative to the pure error. There is a 18.15% chance that a "Lack of Fit F-value", due to noise. Non-significant lack of fit is good

R-Squared 0.9394
Adj R-Squared 0.9233
Pred R-Squared 0.8829

The "Pred R-Squared" of 0.8829 is in reasonable agreement with the "Adj R-Squared" of 0.9233.

3.3 Model Equations

1. Final equation in Terms of code Factors:

Removal Efficiency (%) =
+61.83
+6.72 * A
+4.44 * B
-9.32 * C
-3.51 * B2

2. Final equation in Terms of Actual Factors:

Removal Efficiency (%) =
+24.70331
+26.87500 * Adsorbent dosage
+12.75496 * pH
-0.18638 * Adsorbate volume
-0.87776 * pH2

Table 3: Predicted versus Actual Values at Standard Order

Standard Order	***Actual Order***	***Predicted Value***
1	55.20	56.48
2	70.80	69.92
3	62.80	65.37
4	72.20	78.80
5	38.70	37.84
6	45.30	51.28
7	44.00	46.73
8	64.30	60.17
9	50.70	48.40
10	78.50	75.27
11	40.00	38.90
12	58.90	56.68
13	81.20	80.47
14	41.00	43.20
15	60.70	61.83
16	66.20	61.83
17	61.30	61.83
18	62.00	61.83
19	60.90	61.83
20	65.80	61.83

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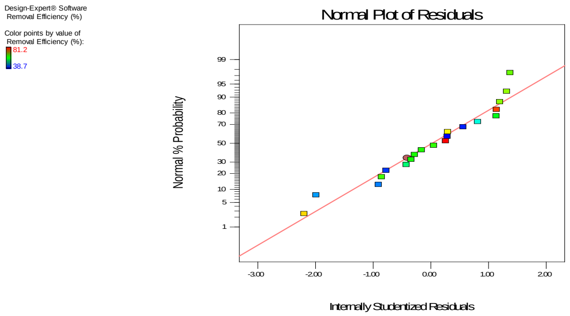
4. Results and Discussion

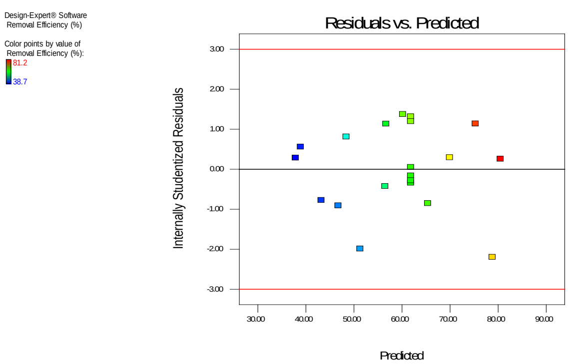
Normal Plot of Residual

The normal probability plot indicates whether the residuals follow a normal distribution, in which case the points will follow a straight line. Expect some moderate scatter even with normal data. Look only for definite patterns like an "S-shaped" curve, which indicates that a transformation of the response may provide a better analysis.



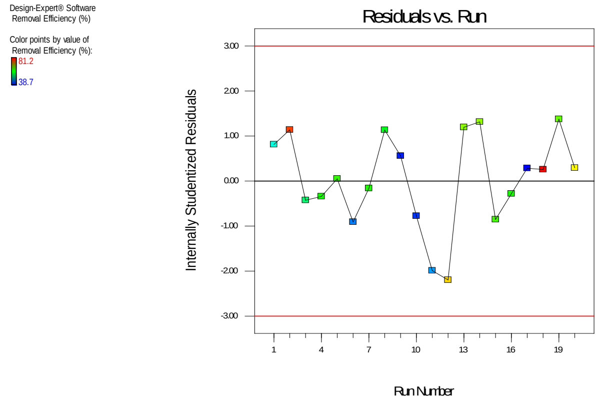
Residuals vs Predicted Plot

This is a plot of the residuals versus the ascending predicted response values. It tests the assumption of constant variance. The plot should be a random scatter (constant range of residuals across the graph.) Expanding variance ("megaphone pattern <") in this plot indicates the need for a transformation.



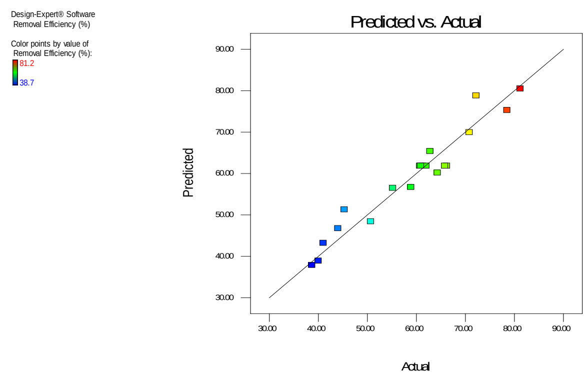
Residuals vs Run

This is a plot of the residuals versus the experimental run order. It allows you to check for lurking variables that may have influenced the response during the experiment. The plot should show a random scatter. Trends indicate a time-related variable lurking in the background. Blocking and randomization provide insurance against trends ruining the analysis.

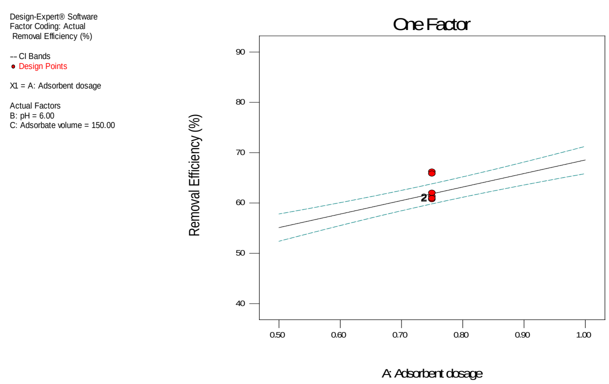


Residuals vs Actual

A graph of the actual response values versus the predicted response values. It helps you detect a value, or group of values, that are not easily predicted by the model. The data points should be split evenly by the 45 degree line.



Model Graphs



The result of the comparative analysis and treatment of well waters in Ebonyi state, Nigeria showed that the standard of well waters in the state in terms of chemical, physical and microbiological data are well below the standard required by the Nigeria Standard for Drinking Water Qualities (NSDWQ) and World Health Organization (WHO). The results of the well waters based on chemical, physical and microbiological data are as follows: nitrates is 18.30 mg/l, magnesium is 7.05mg/l, turbidity is 6.48 NTU, total coliform is 611.00 cfu/ml Escherichia coli 6.92cfu/100ml, plate count 2.62 and faecal streptococci is 141.23 cfu/100ml. but the acceptable values by NSDWQ/WHO are 50.00/10.00mg/l, 0.20/150mg/l, 5.00NTU/-, 10.00/0cfu/ml, 0/0cfu/100ml, 0/0, 0/0cfu/100ml respectively. Therefore, the standard of well waters in the state in terms of chemical, physical and microbiological data are well below the standard of NSDWQ and WHO.

4. Conclusions

The chemical, physical and microbiological data of well waters in Ebonyi state are below the standard required by the Nigeria Standard for Drinking Water Qualities (NSDWQ) and World Health Organization (WHO). Therefore, treatment of the microbilogically contaminated well waters was carried out using chlorine while only four well waters have their iron content above the NSDWQ limit. The reduction of the iron to NSDWQ limit was done using adsorption techniques. For best optimization, the adsorbent dosage of 1.00g, pH of 7.26, adsorbate volume of 100mls with predicted iron removal efficiency of 79.2774% at desirability of 0.955. Hence, the causes of some water borne diseases in Ebonyi State Nigeria are due to the consumption of infected well waters that are not safe for drinking unless treated.

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