WASOT
www.wasot2012.org

Ifejimalu Augustine, Toxicology Digest Vol. 2 (1): 61-83 (2018)

Toxicology Digest

Effect of Rice Milling Activities on Water Qualities in a Major Rice Producing Area of Southeastern Nigeria

Ifejimalu Augustine Chukwuemeka
Department of Agriculture, Federal University Ndufu – Alike, Ikwo, Ebonyi State.
E-mail: austol20@gmail.com +234 706 278 0064

Abstract

A research was conducted in 2015 and 2016 to evaluate the effects of rice milling activities on water qualities in a major rice producing area of south-eastern Nigeria. Samples were collected from a tap water at Faculty of Agriculture and Natural Resources Management, FARM, EBSU (control) and Onuebonyi river within the site at three points: upstream (W_1), midstream (W_2) and downstream (W_3) to assess water quality. Results for water qualities showed that respective temperature values for control, W_1 W_2 and W_3 were 25.0^{0}C, 29.20^{0}C, 29.0^{0}C and 28.50^{0}C in 2012 and 26.0^{0}C, 29.50^{0}C, 29.50^{0}C and 29.50^{0}C in 2013, which was higher than World Health Organization permissible standard of 23^{0}C. Water quality parameters of the rice mill site (W_1, W_2 and W_3) were in most cases higher than the values obtained for control area; and the WHO permissible standard limit. There should be proper fencing off of ponds and river with concrete platform that will not allow run-off to enter them. Washing of scrap metals in water bodies should be discouraged. Waste dumping in water ways should be controlled by effective monitoring and legislation.

Keywords: *Rice milling activities, water qualities, permissible standard, waste dumping*

Introduction

Humans have always inhabited two worlds. One is the natural world of plants, animals, soil, air and water that preceded us by billions of years and of which we are a part. The other is the world of social institutions and artifacts that we create for ourselves using science, technology, and political organization. Both worlds are essential to our lives, but integrating them successfully causes enduring tensions. Water as natural resource play an important role in preserving the existence, as well as, the development of our planet and its people. The rapid increase of population and intense industrial activities in our planet have resulted in large quantities of organic and inorganic wastes being discharged into our environment, thus, giving rise to serious environmental problems and deterioration of the health, and well-being of human populations or agro-ecosystems. The significance of environmental factors to the health and well-being of human population is increasingly apparent (Rosenstock, 2003; World Health Organization, 2010b). Where earlier people had limited ability to alter their surroundings, we now have power to extract and consume resources, produce wastes, and modify our world in ways that threaten both our continued existence and that of many organisms with which we share the planet (Brown, 2003). To ensure a sustainable future for ourselves and future generations, we need to understand something about how our world works, what we are doing to it, and what we can do to protect and improve it (International Council for Science, 2002).

In a broader definition, environment is everything that affects an organism during its lifetime. It is the total surroundings of an organism (Gewin, 2002). Since human inhabit the natural world as well as the technological, social and cultural world, all constitute important parts of our environment (Sanderson, 2010). Environmental pollution is a worldwide problem and its potential to influence the health of human population is great (Fereidoun *et al.,* 2007; Progressive Insurance, 2005). Pollution reaches its most serious proportions in the densely settled urban-industrial centres of the more developed countries (Kromm, 1993). In poor countries of the world, more than 80% of polluted water has been used for irrigation, with only 70-80% food and living security in industrial-urban and semi-urban areas (Mara and Cairncross, 1989).

Man’s increasing control of his environment often creates conflicts between human goals and natural processes (Ashok, 2008). Industry, clustered in urban and semi-urban areas surrounded by densely populated, low-income localities, continues to pollute the environment with impunity (Government of Pakistan, 2009). Industries turn out wastes which are peculiar in terms of type, volume and frequency depending on the type of industry and population that uses the product (Adekunle, 2008). Industrial waste is the most common source of soil, water and air pollution in the present day (Ogedengbe and Akinbile, 2004), and it increases yearly due to the fact that industries are increasing because most countries are getting industrialized.

Rice mill waste is an agricultural waste obtained from the milling of rice. About 10^8 tons of rice mill waste is generated annually in the world (Tracy and Nicholas, 1992). In Nigeria, about 2.0 million tons of rice is produced annually and Abakaliki milling complex produce about 500 tons of rice mill husk yearly (Beagle, 2008). The rice husk is burnt constantly of which the smoke and dust constitute environmental pollution (Nnadi, 2007). Larson *et al.* (1999) reported that rice husk is very rich in potassium (K), low in phosphorus (P), poor to medium in nitrogen (N) and its content of secondary elements is highly variable. However, heavy dumping of organic waste is known to have adverse effect on soil, water and air in the surrounding environment. Tracy and Nicholas (1992) reported that heavy dumping of rice mill waste at the south west of Holland caused air pollution and soil contamination in that area.

Abakaliki agricultural zone of the south-eastern Nigeria is a major rice producing and processing area in Nigeria. Abakaliki in particular and Ebonyi State in general, depend on agriculture for livelihood and sustainable development. Sustainable livelihood and development go with sustainable water health. Large quantities of rice husk are produced annually around the milling centres. These materials heap around the milling centres and over the years have developed into environmental eyesores. The waste has become problematic and the common way of management has been to burn them. There are concerns as to their effect on the water health of the Abakaliki environment, hence the subject of this research.

Materials and Methods

Site Description

The study area is Abakaliki, while the study site is Abakaliki Rice Mill Industry. The area is located in Abakaliki the capital city of Ebonyi State. It is situated in the south eastern part of Nigeria and has a population of about 160 thousand people accounting for about ten percent of the state population (National Population Census, NPC, 2006). Abakaliki rice mill industry is located on latitude $06^0\ 4^1$N and longitude $8^0\ 65^1$E. The rice mill industry is located along old Abakaliki- Ogoja road on the outskirts of the town and close to the Ebonyi State University. It covers approximately an area of about 500m^2. Abakaliki, one of the thirteen Local Government Area in Ebonyi State, was made the state capital in 1996 (Echiegu, 2007). The rainfall pattern is bimodal (April – July and September – November), with a short dry spell in August normally referred to as “August break”. The total annual rainfall in the area ranges from 1500 - 2000mm, with a mean of 1800mm. At the onset of rainfall, it is torrential and violent sometimes lasting for one to two hours (Okonkwo and Ogu, 2002).

The area is characterized by high temperatures with minimum mean daily temperature of 31^0C throughout the year. According to Overseas Development of Natural Resources (ODNRI, 1989), humidity is high (80%). The lowest (60%) level occurs during the dry season between December and April, before the rainy season begins. Geologically, the area is underlain with sedimentary rocks derived from successive.

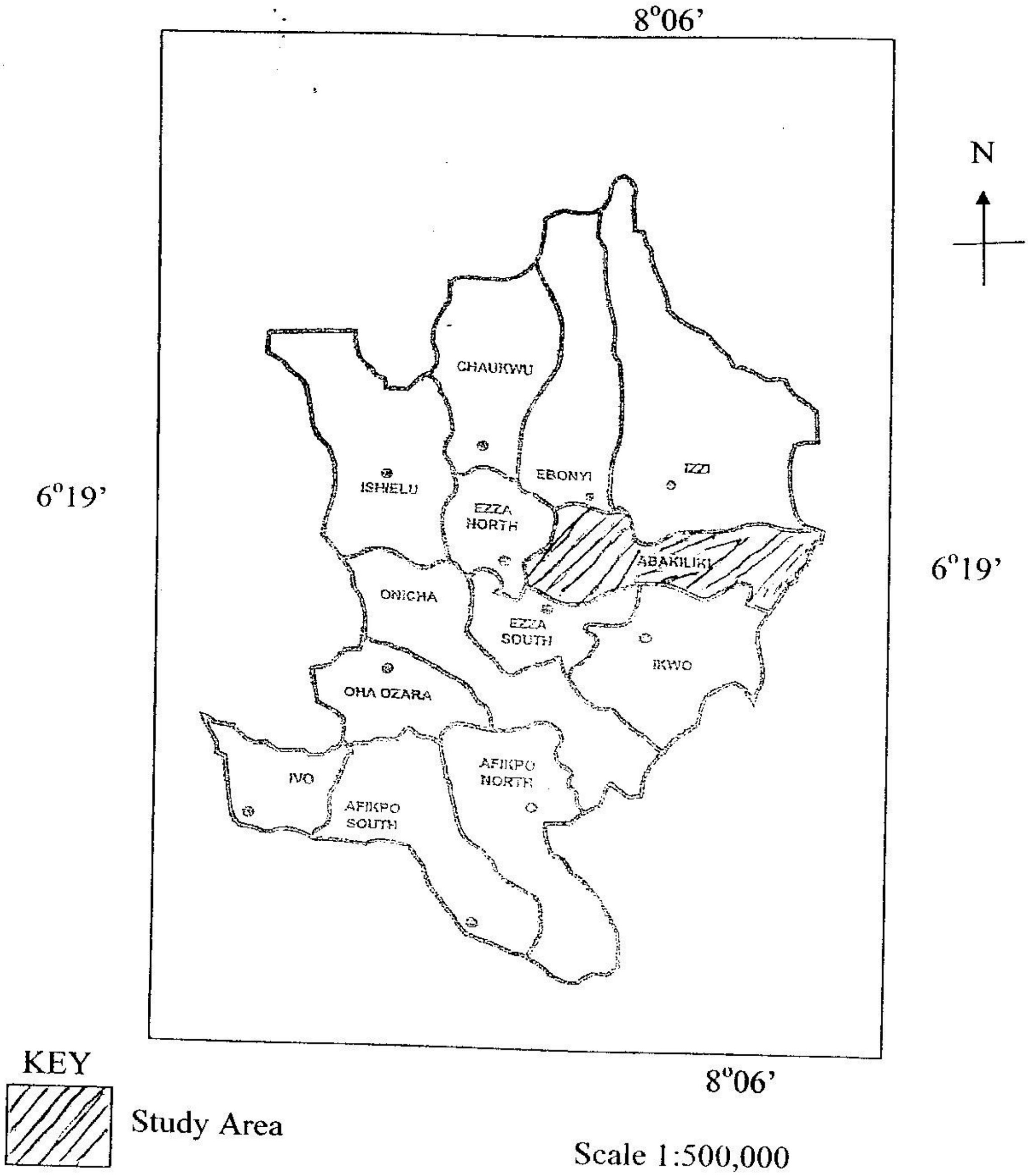

Figure 1: Map of Ebonyi State, South-eastern Nigeria showing Abakaliki (the Study Area)

The area has marine deposits of the cretaceous and tertiary periods. The soil belongs to the order ultisol derived from shale and classified as typic haplustult. According to the Federal Department of Agriculture and Land Resources (FDALR, 1985), Abakaliki agricultural zone lies within "Asu River group" and consists of olive brown sandy shale, fine-grained sandstone and mud stones. These conditions favour rice cultivation. The sampling materials included: sterilized Water bottles, thermometer, masking tape, marker, gloves, rain boots, cooler and ice blocks were used for collecting water samples.

Sampling and samples handling were carried out as recommended by WHO (2000) and Okafor (1985). Water samples collected were taken to the lab immediately to avoid temperature loses and subsequent microbial decline.

Water analysis

The following parameters were determined:

Temperature: This was determined at the point of sampling using a mercury thermometer with calibration 0-100^{0}C. The thermometer was placed vertically into the collected sample, immersing the bulb containing the mercury into the water. It was then allowed to stand till temperature reading was steady. The steady reading was then recorded (A.O.A.C., 1998).

Water sampling

Water samples (1000ml) were collected at 0 – 30cm from Onuebonyi River in the study site, as follows:

Control – Tap Water, Ebonyi State Water Board
Sample W_1 – Upstream
Sample W_2 – Midstream
Sample W_3 – Downstream

Odour: This was determined through the use of sensory evaluation penal according to methods of APHA (1998).

pH: This was determined in the laboratory by the use of an electric digital pH meter. 100ml of the water sample was measured into a beaker. The pH meter electrode was dipped into the water in the beaker and allowed for some minutes to detect the reading. After each sample, the electrode of the pH meter was dipped in distilled water to rinse it before the next sample (A.O.A.C., 1998).

Conductivity: This was determined using the conductivity meter (APHA, 1998).

Turbidity: This was estimated by comparing the turbidity of the water sample with the ampoule of standard turbidity, by holding both ampoules side by side after thorough shaking (A.O.A.C., 1998).

Total hardness: 50ml of the water sample was weighed in a conical flask and 1ml of buffer-10 solution was added to it. 1ml of 5% Na_2S solution was added. Then 3 drops (100 - 200mg) of trio T black indicator was added until the sample turned wine red. The content was titrated with 0.01m EDTA solution until the solutions turned blue (APHA, 1998).

Total solid (TS): Three beakers were washed with tap water and rinsed with distilled water. The beakers were oven-dried, cabled in desiccators, labeled accordingly and weighed (W_1). 50ml of the unfiltered water sample was cooled in desiccators and re-weighed (W_2). The difference in weight of empty beaker (W_1) and beaker with sample after drying (W_2) represents the total solid. The formular is given by:

$$\text{Total solid } (T_s) = \left(\frac{TS\, residue\, X\, 1000}{vol. of\ sampleused}\right) Mg/L \qquad - \qquad (6)$$

Total dissolved solid (TDS): The procedure is the same with TS, but the only difference is that filtered water samples were used. Empty beaker was weighed. 0mls of the sample was measured and filtered into the weighed beaker and heated to dryness. The beaker was cooled and then weighed. The difference in the two weight of the beaker gives the weight of dissolved solid. The values were then applied to the formular below:

$$TDS = \left(\frac{T.D.S\ X\ 1000\ x\ 1000}{vol.\ of\ sample}\right) Mg/L \qquad -- \quad - \qquad (7)$$

Total suspended solid (TSS): This was determined using the formular:

$$TSS = TS - TDS \qquad - \quad - \quad - \quad - \quad - \quad - \qquad (8)$$

Acidity: This was determined using titration method by measuring 10ml of the water samples into a 250ml conical flask and 3 drops of phenolphthalein indicator was added to NaOH solution. A calculation was made using the formular:

Acidity = $\left(\dfrac{T.V\ X\ N\ X\ 50\ x\ 1000}{vol.\ of\ \ sample} \right) Mg/L$ - - - (9)

Where TV = Titrated value

N = Normality of NaOH

Alkalinity: This was determined by measuring 10ml of the water sample into a conical flask. 3 drops of methyl orange indictor was added to the sample and it was titrated against O.1N of HCl. It was then calculated using the formular:

Alkalinity = $\left(\dfrac{T.V\ X\ N\ X\ 50\ x\ 1000}{vol.\ of\ \ sample} \right) Mg/L$ - (10)

Where, TV = Titrated volume

N = Normality of the acid

Calcium: 10mls of the water sample was pipette into a 250ml conical flask. 10ml of distilled water was added into the conical flask to make it up to 20mls. 4mls of 8m KOH solution was added into the flask and the entire mixture was shaken thoroughly and allowed to stand for 4 minutes. 30mg or a pinch each of (Analytical grade) AR potassium cyanide and AR hydroxylamine hydrochloride were added into the conical flask containing the solution mixture. The entire content was swirled until the solid added dissolved. 0.2g (or 3 drops) of fat and reader indicator was added and shaken. After shaking the solution mixture in the conical flask, this solution was titrated against 0.01m EDTA from the burette (EDTA disodium Ethylamine diamine tetraracatic acid). Titration continued until the colour of the solution changed from dark red to blue (APHA, 1998).

Chloride: 50ml of each of the water sample was measured into 250ml conical flask respectively. The pH of the sample was adjusted to between 6.00 to 8.50 with sodium bicarbonate or nitric acid. Then 2 drops of O.I M of potassium chromate indicator was added into each of the sample in the conical flask. The samples were then titrated with a standard silver nitrate (O.IN) in the burette.

Chloride (Mg/L) = $\dfrac{Titre\,value\,X\ N(AgNO_3)X\,35{,}500}{ml\,of\ sample\ used}$ -(11)

Sulphate: This was determined by measuring 25ml of the water sample into a 25ml conical flask. 1ml of conc. HCL was then added and the mixture shaken thoroughly for proper mixing. The mixture is then heated to boil. 20 ml of 25% barium chloride was gradually added into the solution and boiled for 5mins. 2ml of NH_3 and 5ml of 0.01N EDTA was also added and boiled for 5mn (A.O.A.C., 1998).

Chemical oxygen demand (COD): 10mls of the water sample was measured into a 250ml conical flask. 5ml of 0.025N potassium chromate ($K_2Cr_2O_7$) was added. Also 15ml of conc. H_2SO_4 and 40ml of distilled water were added, and then shaken vigorously for proper mixing.

$$COD = \frac{T_2 - T_1 \ X \ 0.025 \ X 1000 \ X \ 8}{Vol.\ of\ \ sample\ used} \quad - \quad - \quad (12)$$

Where T_2 = Titre value of blank

T_1 = Titre value of sample

8 = Dilution factor of 8 times

100 = Conversion to litre

0.025= 1ml of 0.025N ferrous Ammonium sulphate liberates 0.025mgO_2.

Dissolved oxygen (DO): 20mls of the water sample was pipette with 1m of potassium fluoride or sodium fluoride added. 20mls of 0.1m manganese sulphate ($MnSO_4$) and 2ml of alkaline iodide oxide solution were then added. Fresh starch indicator was prepared. The solution was titrated with 0.025N sodium thiosulphate ($Na_2S_2O_3$) until a clear colour is observed, then 5ml of starch indicator was added.

$$DO = \frac{T \, X \, 0.025 \ X \ 8000}{203.39} \quad - \quad - \quad - \quad - \quad (13)$$

Where, 203.39 = weight of sodium thiosulphate

8000 = DO factor

T = Titre value

Biochemical oxygen demand (BOD): BOD was determined using the formular:

$$BOD = (DO + COD)\ mg/L \quad - \quad - \quad - \quad (14)$$

Phosphorus (P): This was determined by titration method (APHA, 1998).

Magnesium (Mg): 10ml of the water sample was pipetted into a 250ml conical flask. 10ml of distilled water was added to make up to 20mls. 5mls of buffer 10 was added to the solution. The solution was filtrated against 0.01M EDTA until pure blue end point was reached (A.O.A.C, 1998).

Heavy metal content of water: This was read off with spectrophotometer wavelength (APHA, 1998).

Results of water analysis were compared to World Health Organization (WHO) Standard for Drinking Water Quality (WHO, 2011), used by the National Agency for Food and Drug Administration and Control (NAFDAC).

Data Analysis

The data collected were analyzed using standard error and coefficient of variation (CV %) as recommended by Steel and Torrie (1980). Parameters determined were compared with existing world standards (WHO, 2011).

Results

Effects of Rice Milling Activities on Water Properties

a. Effects of rice milling activities on temperature, odour, pH and conductivity of water

Results of the effect of rice milling activities on temperature, odour, pH and conductivity of water are presented in Table 1. The Table showed that Control (Tap water, Ebonyi State Water Board) recorded lower value on water temperature with 25.0^0C and 26.0^0C in 2015 and 2016 respectively relative to W_1 (Upstream), W_2 (Midstream) and W_3 (Downstream). Control was lower than W_1, W_2 and W_3 by 17, 16 and 14% in 2015; while in 2016, control was lower than W_1, W_2 and W_3 by 13, 13 and 13% respectively.There was no variation among different sampling points for water temperatures in 2015 (CV = 7.06%) and 2016 (CV = 6.11%). All values were observed to be above World Health Organization (WHO) permissible limit of 23^0C.

In terms of odour (Table 1), samples were observed Odourless in 2015 and 2016. pH of the water (Table 1) were 6.18, 5.50 and 5.91 in 2012 and 6.64, 7.18 and 7.10 in 2013 for W_1, W_2 and W_3 respectively. Water pH was higher in W_1 relative to control, W_2 and W_3 by 11, 11 and 4% respectively in 2015. In 2016, the order of decrease in water pH was control < W_1 < W_3 < W_2. Control was lower than W_1, W_2 and W_3 by 19, 28 and 27% respectively in 2016. There was no variation among different sampling points in 2015

(CV = 5.75%) and 2016 (CV = 10.74%). The water pH values in 2015 and 2016 were below the World Health Organization (WHO) range of 6.5-8.5.

Water conductivity (Table 1) recorded high value in W_2 (242 μscm^{-3}) relative to control (80.60 μscm^{-3}), W_1 (70.10μscm^{-3}) and W_3 (144μscm^{-3}). In 2013, W_1 (195.60μscm^{-3}) recorded the highest value compared to control (86.60 μscm^{-3}), W_2 (180.40 μscm^{-3}) and W_3 (110.90 μscm^{-3}). In 2015, the order of increase was W_2> W_3 > control > W_1. In 2016, control was lower than W_1, W_2 and W_3 by 126, 108 and 28% respectively. There was no variation among different sampling points in 2015 (CV = 31.11%) and 2016 (CV = 36.85%). Sampling points recorded values which were below WHO maximum permissible limit of 1200μscm^{-3}

Table 1: Effects of Rice Milling Activities on Temperature, Odour, pH and Conductivity of Water

	2015				2016			
Sample	**Temperature (ºC)**	**Odour**	**pH**	**Conductivity (μscm^{-3})**	**Temperature (ºC)**	**Odour**	**pH**	**Conductivity (μscm^{-3})**
WHO Standard	23.00	Unobjectionable	6.5 - 8.5	1200				
Control	25.00 ± 1.69	Odourless	5.47 ± 0.17	80.60 ± 36.40	26.00 ± 1.52	Odourless	5.60 ± 0.58	86.60 ± 32.78
W_1	29.20 ± 0.73	Odourless	6.18 ± 0.24	170.00 ± 15.21	29.50 ± 0.50	Odourless	6.64 ± 0.02	195.60 ± 30.15
W_2	29.00 ± 0.62	Odourless	5.50 ± 0.16	180.00 ± 20.99	29.50 ± 0.50	Odourless	7.18 ± 0.33	180.40 ± 21.37
W_3	28.50 ± 0.33	Odourless	5.91 ± 0.08	144.00 ± 0.20	29.50 ± 0.50	Odourless	7.10 ± 0.23	110.90 ± 18.75
CV (%)	7.06	-	5.75	31.11	6.11	-	10.71	36.85

Note: WHO = World Health Organisation; Control = Tap water, Ebonyi State Water Board;
W_1 = Upstream; W_2 = Midstream; W_3 = Downstream

Source: Field Work (2015 and 2016).

b. Effects of rice milling activities on turbidity, total hardness, total solid and total dissolved solid of water

Result of the effect of rice milling activities on turbidity, total hardness, total solid and total dissolved solid of water are presented in Table 2. The table (Table 2) showed that water turbidity were 20.18NTU, 21.87NTU and 28.0NTU in 2015 and 94.0NTU, 49.20NTU 55.0NTU in 2016 for W_1, W_2 and W_3 respectively. These values were higher than control for the two years (19.10NTU and 22.0NTU) respectively. In 2015, W_3 was higher than control,

Table 2: Effects of Rice Milling Activities on Turbidity, Total Hardness, Total Solid and Total Dissolved Solid of Water

Sample	2015				2016			
	Turbidity (NTU)	**Total Hardness (mgL^{-1})**	**Total Solid (mgL^{-1})**	**Total Dissolved Solid (mgL^{-1})**	**Turbidity (NTU)**	**Total Hardness (mgL^{-1})**	**Total Solid (mgL^{-1})**	**Total Dissolved Solid (mgL^{-1})**
WHO Standard	5.00	500.0	1500.0	500.0				
Control	19.10 ± 1.84	28.20 ± 6.50	0.60 ± 0.95	0.20 ± 0.14	22.00 ± 19.08	2.50 ± 7.90	0.80 ± 0.91	0.30 ± 0.16
W_1	20.18 ± 1.24	58.00 ± 10.65	4.00 ± 1.101	1.00 ± 0.32	94.00 ± 22.49	20.40 ± 2.44	4.00 ± 0.94	1.00 ± 0.24
W_2	21.87 ± 0.24	32.00 ± 4.36	3.40 ± 0.66	0.40 ± 0.03	49.20 ± 3.38	5.80 ± 6.41	3.70 ± 0.76	0.60 ± 0.01
W_3	28.00 ± 3.30	40.00 ± 0.26	1.00 ± 0.75	0.20 ± 0.14	55.00 ± 0.03	36.0 ± 11.44	1.00 ± 0.80	0.40 ± 0.10
CV (%)	24.48	33.50	75.56	83.14	53.93	94.00	71.85	53.45

Note: WHO = World Health Organisation; Control = Tap water, Ebonyi State Water Board; W_1 = Upstream; W_2 = Midstream; W_3 = Downstream

Source: Field Work (2015 and 2016).

W_1 and W_2 by 32, 28 and 22% respectively. In 2016, the order of decrease was control < W_2 < W_3 <W_1. In 2015, there was no variation among different sampling points (CV = 24.48%), while in 2016 there was variation (CV = 53.93%). The turbidity of water samples were all above WHO limit of 5.0 NTU in 2015 and 2016.

Total hardness (Table 2) was lower in control in 2015 (28.20mgL^{-1}) and 2016 (2.50mgL^{-1}). In 2015, control was lower than W_1, W_2 and W_3 by 106, 13 and 42% respectively. Again in 2016, control was lower than W_1, W_2 and W_3 by 716, 132 and 134% respectively. There was no variation among different sampling points in 2015 (CV = 33.50%), but there was variation in 2016 (CV = 94.0%). All values were below WHO limit of 500mgL^{-1}.

Total solid (Table 2) were 4.0mgL^{-1}, 3.40mgL^{-1} and 1.0mgL^{-1} in 2015 and 4.0mgL^{-1}, 3.70mgL^{-1} and 1.0mgL^{-1} in 2016 for W_1, W_2 and W_3 respectively. These values were higher than control (0.60mgL^{-1} and 0.80mgL^{-1}) for the two years. In 2015, the order of increase was W_1 (Upstream)> W_2 (Midstream) > W_3 (Downstream) > control (Tap water); while in 2016, total solid decreased as follows: control < W_3 <W_2 < W_1. There was variation among different sampling points in 2015 (CV = 75.56%) and 2016 (CV = 71.85%). All values were below WHO permissible limit of 1500mgL^{-1}.

The effect of rice milling activities on total dissolved solid of water (Table 2) was higher in W_1 (1.0mgL^{-1}) in 2015 and 2016. In 2015, this W_1 value represents 80, 60 and 80% increase over control, W_2 and W_3 respectively. In 2016, the order of decrease was control < W_3 < W_2 < W_1. Total dissolved solid recorded variation among different sampling points in 2015 (CV = 83.14%) and 2016 (CV = 53.45%). Values recorded were below WHO limit of 500mgL^{-1}.

c. Effects of rice milling activities on total suspended solid, acidity, alkalinity and calcium (Ca) content of water

Result of the effects of rice milling activities on total suspended solid, acidity, alkalinity and calcium content of water are presented in Table 3. The Table showed that the effect of rice milling activities on total suspended solid (TSS) of water was higher in W_1 (3.0mgL^{-1}) and W_2 (3.0mgL^{-1}) compared to control (0.30mgL^{-1}) and W_3 (0.40mgL^{-1}) in 2015; and higher in W_2 (4.0mgl^{-1}) relative to control (0.30mgL^{-1}), W_1 (3.30mgL^{-1}) and W_3 (0.50mgL^{-1}) in

2016. In 2016, the trend was $W_2 > W_1 > W_3 >$ control. There was variation among different sampling points in 2015 (CV = 91.05%) and 2013 (CV = 93.60%). All the values recorded for TSS in 2015 and 2016 were below WHO standard limit of 10mgL^{-1}.

Effect of rice milling activities on water acidity (Table 3) was higher in W_2 (10.0mgL^{-1}) relative to control area (3.0mgL^{-1}), W_1 (5.0mgL^{-1}) and W_3 (5.0mgL^{-1}) in 2015; and both W_2 (10.0mgL^{-1}) and W_3 (10.0mgL^{-1}) compared to control (6.0mgL^{-1}) and W_1 (5.0mgL^{-1}) in 2016. Control was lower than W_1, W_2 and W_3 by 67, 233 and 67% respectively in 2015. There was variation among different sampling points in 2012 (CV = 51.49%), while there was no variation in 2016 (CV = 33.94%). There was no WHO limit available for comparison.

Table 3: Effects Rice Milling Activities on Total Suspended Solid, Acidity, Alkalinity and Calcium (Ca) Content of Water

Sample	2015 Total Suspended Solid (mgL^{-1})	2015 Acidity (mgL^{-1})	2015 Alkalinity (mgL^{-1})	2015 Ca (mgL^{-1})	2016 Total Suspended Solid (mgL^{-1})	2016 Acidity (mgL^{-1})	2016 Alkalinity (mgL^{-1})	2016 Ca (mgL^{-1})
WHO Standard	10.0	-	100.0	-				
Control	0.30 ± 0.80	3.00 ± 1.62	6.00 ± 0.29	1.91 ± 0.05	0.30 ± 0.10	6.00 ± 1.01	5.00 ± 5.05	1.92 ± 0.73
W_1	3.00 ± 0.76	5.00 ± 0.46	6.00 ± 0.29	1.90 ± 0.06	3.30 ± 0.75	5.00 ± 1.59	15.00 ± 0.72	2.08 ± 0.64
W_2	3.00 ± 0.76	10.00 ± 2.42	5.00 ± 0.29	2.50 ± 0.29	4.00 ± 1.14	10.00 ± 1.30	25.00 ± 6.50	4.63 ± 0.83
W_3	0.40 ± 0.74	5.00 ± 0.46	5.00 ± 0.29	1.70 ± 0.17	0.50 ± 0.88	10.00 ± 1.30	10.00 ± 2.17	4.14 ± 0.55
CV (%)	91.05	51.49	10.49	17.50	93.60	33.94	62.11	43.57

Note: WHO = World Health Organisation; Control = Tap water, Ebonyi State Water Board; W_1 = Upstream; W_2 = Midstream; W_3 = Downstream
Source: Field Work (2015 and 2016).

Alkalinity (Table 3) was higher in control (6.0mgL^{-1}) and W_1 (6.0mgL^{-1}) compared to W_3 (5.0mgL^{-1}) and W_3 (5.0mgL^{-1}) in 2015; and W_2 (25.0mgL^{-1}) compared to control (5.0mgL^{-1}), W_1 (15.0mgL^{-1}) and W_3 (10.0mgL^{-1}) in 2016. There was no variation among different sampling points in 2015 (CV = 10.45%), but sampling points were variant in 2016 (CV = 62.11%). All values recorded for water alkalinity were below WHO permissible limit of 100mgL^{-1}.

Table 3 also showed that the calcium (Ca) content of water was higher on W_2

(2.50mgL^{-1}) compared to control (1.91mgL^{-1}), W_1 (1.90mgL^{-1}) and W_3 (1.70mgL^{-1}) in 2015. Again in 2016, W_2 (4.63mgL^{-1}) was higher compared to control (1.92mgL^{-1}), W_1 (2.08mgL^{-1}) and W_3 (4.14mgL^{-1}). Calcium content of water decreased as follows: was W_1 < control < W_3 < W_2 in 2016. Levels of Ca for the different sampling points did not vary in 2015 (CV = 16.70%) and 2016 (CV = 43.57%). There was no WHO limit value available for comparison.

d. Effects of rice milling activities on chloride, sulphate, magnesium (Mg) and phosphorus (P) content of water.

Chloride content of water (Table 4) was 19.0mgL^{-1}, 39.80mgL^{-1} and 21.30mgL^{-1} in 2015 and 100.0mgL^{-1}, 106.0mgL^{-1} and 113.6mgL^{-1} in 2016 for W_1, W_2 and W_3 respectively. These values were higher than control (14.20mgL^{-1} and 19.40mgL^{-1}) for the two years respectively. In 2015, the order of increase was W_2> W_3 > W_1 > control; while in 2016, the trend was control < W_1 < W_2 < W_3. There was no variation among different sampling points in 2015 (CV = 47.14%), while in 2016 sampling points did vary (CV= 51.83%). All values recorded for chloride content of water in 2012 and 2013 were below WHO permissible limit of 250mgL^{-1}. Sulphate levels (Table 4) were lower for control (36.50mgL^{-1}) in 2015; but higher on W_2 (89.80mgL^{-1}) in 2016. In 2015, control was lower than W_1, W_2 and W_3 by 24, 9 and 19% respectively. There was no variation among different sampling points in 2015 (CV = 15.34%), but sample points varied in 2016 (CV = 79.50%). All the values recorded for sulphate content of water in 2015 and 2016 were below WHO limit of 500mgL^{-1} Magnesium levels (Table 4) were higher on W_2 (6.30mgL^{-1}) in 2015, and also on W_2 (7.92mgL^{-1}) in 2016. There was variation among different sampling points in 2015 (CV =77.89%), but sample were not variant in 2016 (CV = 41.49%). All the values recorded were below the WHO limit of 20mgL^{-1}.

Table 4: Effects of Rice Milling Activities on Chloride, Sulphate, Magnesium (Mg) and Phosphorus (P) Content of Water

	2015				2016			
Sample	**Chloride (mgL^{-1})**	**Sulphate (mgl^{-1})**	**Mg (mgL^{-1})**	**P (mgL^{-1})**	**Chloride (mgL^{-1})**	**Sulphate (mgL^{-1})**	**Mg (mgL^{-1})**	**P (mgL^{-1})**
WHO Standard	250.0	500.0	20.0	-				
Control	14.20 ± 5.47	36.50 ± 2.70	0.60 ± 1.47	-	19.40 ± 37.82	20.00 ± 12.47	5.0 ± 0.37	0.10 ± 0.31
W_1	19.40 ± 2.47	45.10 ± 2.26	3.70 ± 0.32	0.98 ± 0.09	100.0 ± 8.72	89.80 ± 27.83	7.01 ± 0.79	0.20 ± 0.20
W_2	39.80 ± 9.31	39.80 ± 0.80	6.30 ± 1.82	1.57 ± 0.25	106.0 ± 12.18	36.60 ± 2.89	7.92 ± 1.32	0.80 ± 0.14
W_3	21.30 ± 1.37	43.30 ± 1.22	2.00 ± 0.66	0.88 ± 0.15	113.6 ± 16.57	20.0 ± 12.47	2.64 ± 1.32	1.20 ± 0.38
CV (%)	47.14	15.34	77.89	26.32	51.53	79.50	41.49	98.18

Note: WHO = World Health Organisation; Control = Tap water, Ebonyi State Water Board; W_1 = Upstream; W_2 = Midstream; W_3 = Downstream
Source: Field Work (2015 and 2016).

Phosphorus levels (Table 4) were higher on W_2 in 2015 with 1.57mgL^{-1} and W_3 (1.20mgL^{-1}) in 2016. Control was lower than W_1, W_2 and W_3 by 100, 700 and 1100% respectively in 2016. There was no variation among different sampling points in 2015 (CV = 26.32%), but they were variant in 2016 (CV=98.18%). There was no WHO limit value for comparison.

e. Effects of rice milling activities on chemical oxygen demand (COD), dissolved oxygen (DO) and biochemical oxygen demand (BOD) of water

Result of the effects of rice milling activities on Chemical Oxygen Demand (COD), Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) of water are presented in Table 5. Lower values of COD was recorded on control in 2015 (44.0mgL^{-1}) and 2016 (2.0mgL^{-1}). In 2015, the order of increase was W_2> W_1> W_3 > control. Control was lower than W_1, W_2 and W_3 by 150, 312 and 296% respectively in 2016. There was variation among different sampling points in 2015 (CV=54.25%), and 2016 (CV = 50.43%). There was no WHO permissible limit standard comparison value for COD.

Water dissolved Oxygen (Table 5) was higher on W_3 (32.50mgL^{-1}) relative to control (9.20mgL^{-1}), W_1 (27.30mgL^{-1}) and W_2 (12.20mgL^{-1}) in 2015; and on W_3 (19.70mgL^{-1}) in 2016 relative to control (4.0mgL^{-1}), W_1 (10.0mgL^{-1}) and W_2

(13.57mgL^{-1}). Control was lower than W_1, W_2 and W_3 by 197, 33 and 253% respectively in 2015. In 2016, control was lower than W_1, W_2 and W_3 by 150, 239 and 393% respectively. There was variation among different sampling points in 2015 (CV = 55.93%) and 2016 (CV = 55.58%). In 2015, all values were above WHO permissible limit except control (9.20mgL^{-1}); while in 2016, W_2 and W_3 were above the permissible limit of WHO (8 – 10.0mg/L).

Table 5: Effects of Rice Milling Activities on Chemical Oxygen Demand (COD), Dissolved Oxygen and Biochemical Oxygen Demand (BOD) of Water

	2015			2016		
Sample	**COD (mgL^{-1})**	**DO (mgL^{-1})**	**BOD (mgL^{-1})**	**COD (mgL^{-1})**	**DO (mgL^{-1})**	**BOD (mgL^{-1})**
WHO Standard	-	8 - 10.0	10.0	-	-	-
Control	44.00±49.65	9.20±6.41	76.50±44.17	2.00±2.19	4.0±4.51	76.5±53.71
W_1	138.0±4.62	27.30±4.04	165.30±7.10	5.00±0.46	10.00±1.05	153.0±9.54
W_2	216.0±49.65	12.20±4.68	228.20±43.42	8.24±1.41	13.57±1.01	237.6±39.30
W_3	122.0±4.62	32.50±7.04	142.0±6.65	7.92±1.23	19.70±4.55	211.0±23.94
CV (%)	54.25	55.93	43.25	50.43	55.58	42.10

Note: WHO = World Health Organisation; Control = Tap water, Ebonyi State Water Board; W_1 = Upstream; W_2 = Midstream; W_3 = Downstream.

Source: Field Work (2015 and 2016).

Table 5 showed that Biochemical Oxygen Demand (BOD) was higher on W_2 in 2015 and 2016 with 228.20mgL^{-1} and 237.60mgL^{-1} respectively. BOD recorded no variation among different sampling points in 2015 (CV = 43.25%) and 2016 (CV = 42.10%). All values were above WHO limit of 10mgL^{-1}.

f. Effects of rice milling activities on heavy metal content of water

Table 6 showed that copper (Cu) levels ranged between 0.001 – 0.05mg/L in 2015 and 2016. W_3 recorded the highest value of 0.05mgL^{-1}in 2016. There was no variation among different sampling points in 2015 (CV = 40.0%), but there was variation among sampling points in 2016 (CV = 99.80%). Values were below WHO permissible limit (2.0mg/L). Iron levels

(Table 6) were higher on W_2 (5.20mgL^{-1}) in 2015 and W_3 (1.82mgL^{-1}) in 2013. In 2015, control was lower than W_1, W_2 and W_3 by 423, 1200 and 500% respectively. There was variation among different sampling points in 2015 (CV = 78.97%) and 2016 (CV = 91.57%). All values were above WHO limit of 3.0mgL^{-1}, with the exception of W_2 (5.20mgL^{-1}) in 2015.

Manganese (Table 6) ranged between 0.01 – 0.10mg/L in 2015 and 2016. Sampling points were variant in 2015 (CV = 96.23%) and 2016 (CV = 96.23%). Values recorded were below WHO limit of 0.4mgL^{-1}.

Zinc levels (Table 6) ranged between 0.01 – 0.03mg/L in 2015 and 2016. There was variation among different sampling points in 2015 (CV = 50.0%) and 2016 (CV= 57.74%). values recorded were below WHO limit of 5.0mgL^{-1}.

Table 6: Effects of Rice Milling Activities on Heavy Metal Content of Water

	2015					2016				
Sample	**Copper (mgL^{-1})**	**Iron (mgL^{-1})**	**Manganese (mgL^{-1})**	**Zinc (mgL^{-1})**	**Aluminum (mgL^{-1})**	**Copper (mgL^{-1})**	**Iron (mgL^{-1})**	**Manganese (mgL^{-1})**	**Zinc (mgL^{-1})**	**Aluminum (mgL^{-1})**
WHO Standard	2.0	3.0	0.4	3.0	0.5					
Control	0.001±5.77	0.40±1.22	0.01±0.03	0.01±5.77	0.45±0.06	0.001±0.01	0.40±0.25	0.01±0.03	0.01+5.77	0.40±0.14
W_1	0.001±5.77	2.09±0.25	0.01±0.03	0.01±5.77	0.31±0.14	.001±5.77	0.01±0.47	0.01±0.03	0.01±5.77	0.20±0.26
W_2	0.002±0.0	5.20±1.55	0.10±0.02	0.02±0.0	0.73±0.10	0.03±5.77	0.10±0.42	0.10±0.02	0.02±0.0	0.80±0.09
W_3	0.002±0.0	2.40±0.07	0.10±0.02	0.03±5.77	0.71±0.09	0.05±0.02	1.82±0.57	0.10±0.02	0.03±5.77	1.20±0.32
CV (%)	40.0	78.97	96.23	50.0	7.27	99.80	91.57	96.23	50.0	76.70

Note: WHO = World Health Organisation; Control = Tap water, Ebonyi State Water Board; W_1 = Upstream; W_2 = Midstream; W_3 = Downstream.

Source: Field Work (2015 and 2016).

Table 6 showed that Aluminum content of water was higher on W2 ($0.73mgL^{-1}$) compared to control ($0.45mgL^{-1}$), W_1 ($0.31mgL^{-1}$) and W_3 ($0.71mgL^{-1}$) in 2015. W3 recorded $1.20mgL^{-1}$ and this higher compared to control ($0.40mgL^{-1}$), W_1 ($0.20mgL^{-1}$) and W_2 ($0.80mgL^{-1}$) in 2016. There was no variation among different sampling points in 2015 (CV= 7.27%), but variation existed among sampling points in 2016 (CV = 67.70%). All values recorded were above WHO limit of $0.5mgL^{-1}$ with the exception of control ($0.45mgL^{-1}$) and W_1 ($0.31mgL^{-1}$) in 2015, and also control ($0.40mgL^{-1}$), W_1 ($20.0mgL^{-1}$) and W_2 ($20.0mgL^{-1}$) in 2016.

Discussion

Result of the study (Table 1) showed higher values of temperature, pH and Conductivity of water in Upstream (W_1), Midstream (W_2) and Downstream (W_3) relative to control (Tap water) in 2015 and 2016. These higher readings recorded in temperature were as a result of the heavy dumping of the rice mill waste and leachate flow into the water body in the study site. According to World Health Organization (WHO, 2011), the maximum permissible limit for temperature, pH and conductivity in drinking water bodies are 23^0C, 6.5-85, and $200µscm^{-3}$ respectively. Therefore, temperature levels of 25.0^0C, 29.20^0C, 29.0^0C and 28.50^0C in 2015 and 26.0^0C, 29.50^0C, 29.50^0C and 29.0^0C obtained for control, W_1, W_2 and W_3 respectively do appear to pose a threat to homeostatic balance and aquatic lives. Hoslam (1990) reported that rise in the temperature of water bodies is attributed to the properties and quantity of effluent of receiving waters, climate and weather. According to Jagi *et al.* (2007), higher temperatures reduce solubility of oxygen in water. In 2015 and 2016, result of the study showed that the water samples were odourless (Table 1). Values recorded in water pH (Table 1) were within World Health Organisation (WHO) permissible limit of 6.5 – 8.5 (WHO, 2011). According to Fakayode (2008), aquatic organisms are heavily affected by pH because most of their metabolic activities are pH dependent. Higher value of water conductivity (Table 1) observed in W2 (Midstream) could be associated with the high value of inorganic dissolved solid such as calcium and chloride. The values obtained for control (Tap water), W_1 (Upstream) and W_3 (Downstream) were within WHO permissible limit for drinking water quality (WHO, 2011). According to the Department of Water Affairs and Forestry (DWAF, 1998), conductivity is a useful indictor of mineralization and salinity or total salt content of a water sample.

Table 2 showed higher values of turbidity, total hardness, total solid and total dissolved solid in W_1, W_2 and W_3 relative to control. Turbidity values of 19.10NTU, 20.18NTU, 21.87NTU and 28.0NTU in 2012 and 22.0NTU, 94.0NTU, 49.20NTU and 55.0NTU in 2016 obtained for control, W_1, W_2 and W_3 were higher compared with WHO standard of 5.0NTU for drinking water quality (WHO, 2011). These were as a result of effluent discharge into Onuebonyi River in the study site. Excessive turbidity causes problem with water purification process such as flocculation and filtration, which may increase treatment cost (DWAF, 1999). Readings obtained for total hardness of water (Table 2) for control, W_1, W_2 and W_3 were within WHO permissible limit (WHO, 2011). Hardness of the water is due to metallic ions of calcium and magnesium in W_1, W_2 and W_3 relative to control. American public Health Association (APHA, 1998) noted that total solids measurement can be useful as an indicator of the effects of run-off from construction, agricultural practices, logging activities and other sources. High total solid (Table 2) values recorded in W_1, W_2 and W_3 were as a result of the leaching of rice mill waste into the water bodies of the study site. Total dissolved solid (TDS) as shown in Table 2 was relatively below WHO permissible limit (WHO, 2011) and proved the water safe in terms of TDS and domestic use.

Results of the study (Table 3) showed that total suspended solid, acidity, alkalinity and calcium (Ca) content of water recorded higher values in W_1, W_2 and W_3 relative to control in 2015 and 2016. Total suspended solid (TSS) as shown in Table 3 was also within the limits of the WHO standards for domestic water in 2015 and 2016. United States Geological Survey (1998) opined that alkalinity is not a pollutant but a total measure of the substance in water that have acid neutralizing ability and should not be confused with pH. The water samples produced values which were within WHO permissible limit (WHO, 2011).

As shown in Table 4, rice milling activities increased chloride, sulphate, magnesium and phosphorus content of water on W_1, W_2 and W_3 relative to control. This could be attributed to effluent from the rice mill waste entering the water body in the study site. Nagpal *et al.* (2003) noted that chloride is not an important factor in surface water but a very important factor in municipal portable water distribution system. Harold (1994) reported that deficiency of magnesium and calcium generally results in cardiovascular disease in adults and poor bone formation in children. Mbah and Onweremadu (2009) observed that phosphorus level in water bodies increased as it received organic wastes, and this is in line with the findings of this work.

COD, DO and BOD of water (Table 5) were higher in rice mill sites than the control, and also higher than the WHO standard. COD of water ranged between 5 – 122.0mgL^{-1} as against control which had 44.0mgL^{-1} and 2.0mgL^{-1} in 2015 and 2016. DO of water ranged between 10.0 – 32.50mgL^{-1} compared to control (9.20mgL^{-1} and 4.0mgL^{-1}) in 2015 and 2016. Also BOD of water was between 142.0 – 237mgL^{-1} against control which had 76.50mgL^{-1} and 76.50mgL^{-1} in 2015 and 2016. According to Ogunfowokan *et al.* (2005), organic and inorganic substances from the environment as well as organic contaminants entering water systems lead to increase in COD of the water system. High COD in water can affect aquatic life and the food chain. According to Shelton (1991), a high BOD and COD in water indicate that the water is polluted, while a lower value is an indicator of good water quality.

Result of the study (Table 6) showed that copper, manganese, lead and Zinc were significant in 2015 and 2016. This could be due to increased rice mill activities within the study site as well as the influence of rain, wind and other agents of denudation. According to Lenntech (2011), heavy metals in water cause infertility, kidney problems and mental disorder in children. Ashraf *et al.* (2010) also observed that heavy metal contamination of water causes health hazard and death of human beings, aquatic life and also disturbs the production of different crops.

Conclusion

Water quality parameters of the rice mill site (W_1, W_2 and W_3) were in most cases higher than the values obtained for control area; and the WHO permissible standard limit. This is an indication that the rice milling activities significantly affected the water quality of the study area.

Acknowledgement

The author is grateful to God for His mercies and favours.

References

Adekunle, A. S. (2008). Impacts of Industrial Effluent on Quality of Well Water within Asa Dam Industrial Estate, Illorin, Nigeria. *Nature and Science, 6 (3):* 1 – 5.

American Public Health Association (APHA) (1998). Communicable Disease Control and Laboratory Procedure. www.apha.org.

Ashok, Jain K. (2008). *Law and Environment.* Ascent Publications, New Delhi.

Ashraf, M. A.; Maah, M. J.; Yusoff, I, and Mehmood, K. (2010). Effects of Polluted Water Irrigation on Environment and Health of people in Jamber, District Kasur, Pakistan, *International Journal of Basic and Applied Sciences, 10 (3),* 37 – 57.

Association of Analytical Chemists (A.O.A.C) (1998). Official methods of analysis, Association of Analytical Chemists, Washington, D.C.

Beagle, C. (2008). Rice Husk Conversion to Energy. *FAO Agricultural Bulletin 3.* FAO, Rome, 125.

Brown. L. (2003). State of the World 2003. Washington DC. *World Watch Institute* 84-92.

Department of Water Affairs and Forestry (DWAF) (1998). Quality of Domestic Water Supplies, Assessment Guide 1 (2nd Ed). Department of Water and Forestry, Dept. of Health and Water Research Commission, 12.

Echiegu, P.U. (2007). Urbanization and its Physical Planning Challenges in Abakaliki Capital Environment, Ebonyi State of Nigeria: JSAF, Vol. 7, No. I, 49 – 56.

Fakayode, S.O. (2008). Impact of Industrial Effluent on water Quality of Receiving Alaro River in Ibadan, Nigeria. AJEAM – RAGEE, 10: 1-3.

Federal Dept. of Agriculture and Land Resources (FDALR). (1985). Reconnaissance Soil Survey of Anambra State, Nigeria. Soil Report, Kaduna.

Fereidoun, H.; Nourddin, M. S.; Rreza, N. A.; Mohsen, A.; Ahmad, R. and Pouria, H. (2007). The Effect of Long – Term Exposure to Particulate Pollution on the Lung Function of Teheranian and Zanjanian Students, Pakistan. *Journal of Physiology, 3 (2),* 1 – 5.

Gewin, V. (2002). Ecosystem Health: The State of the Planet. *Nature* 417:112 - 113.

Government of Pakistan (2009). Economic Survey of Pakistan, Finance Division, Economic Division Wing, Islamabad, 20.

Harold, D. F. (1994). Ground Water Resources of British Columbia, Ministry of Environment, Lands and Parks. 61 - 63.

Hoslam, S. M. (1990). River Pollution and Ecological Perspective. Belhaven Press.

International Council for Science (ICS) (2003). Report of the Scientific an Technological Community to the World Summit on Sustainable Development (www.sustainability science.org/Keydocs/)

Jagi, M. O.; Bamgbose, O.; Odukoya, O. O. and Arowolo, T. A. (2007). Water Quality Assessment of Ogun River, South West Nigeria. *Environmental Mon. Assess., 133(1-3),* 477-482.

Kromm, D. E. (1993). Response to Air pollution in Ljubljana, Yugoslaria, *Annals of the Association of American Geographers, 63 (2),* 208 – 217.

Larson, W. E.; Hoh, R. and Charlson, C. W. (1999). Residues from Soil Conservation in: Osch word, W. R. (ed.), Crop Residue Management Systems. *American Society of*

*Agronomy Special Publication No.*31:1– 15.

Lenntech, A. (2011). Water Treatment Solutions and Applications: Chemical Properties of Phosphorus and its Health Effects. 602 - 665.

Mara, D. and Cairncross, S. (1989). Guidelines for Safe Use of Wastewater and Excreta in Agriculture; Measures for Public Protection. World Health organization, Geneva.

Mbah, C. N and Onweremadu, E. U. (2009). Effect of Organic and Mineral Fertilizer Input on Soil and Maize Grain Yield in an Acid Ultisol in Abakaliki- South Eastern Nigeria; *American- Eurasian Journal of Agronomy 2 (1),* 07 -12.

Nagpal, N. K.; Levy, D. A. and Mcdonald, D. D. (2003). Ambient Water Quality Guideline for Chloride.

National Population Census (NPC)(2006). Final Results of 2006 Population Census of Ebonyi State, Nigeria, National Population Commission.

Nnadi, L. A. (2007). The Role of Residues in Soil Conservation and Fertility of Cultivated Savannah Soils. Paper Presented at the 3rd Annual Conference of the Agricultural Society of Nigeria held on 25th July, 2007, Ahmadu Bello University, Zaria.

Ogedengbe, K. and Akinbile, C. O. (2004). Impact of Industrial Pollutants on Quality of Ground and Surface Waters at Oluyole Industrial Estate, Ibadan, Nigeria. *Nig. Jnl. of Technological Development, 4(2)*, 139 –144.

Ogunfowokan, A. O; Okok, E. K.; Adenuga, A. A. and Asubiojo, O. I. (2005). Assessment of the Impact of Point Source Pollution from University, Sewage: Treatment Oxidation Points on the receiving Stream- A Preliminary Study. *Journal of Applied Science 6(1)*36 - 43.

Okafor, N. (1985) Aquatic and Waste Microbiology, 1st Ed., Fourth Dimension Publishing co. Ltd, Enugu, Nigeria, 107 – 127.

Okonkwo, C. I. and Ogu, I. (2002). Assessment of the potentials of *Giricidum Sepium and Panicum Maximum* Biomass used as green Manure in Soil Nutrient Improvement and Yield of Maize; *Journal of Arid Agriculture, 12:* 51 – 56.

Overseas Development of Natural Resources Institute (ODNRI) (1989). Nigeria Profile of Agricultural Potential, ODA, United Kingdom, 40- 50.

Progressive Insurance, (2005). Pollution Impact on Human Health. Retrieved from http://www.progressiveic.com/n25feb05.htm

Rosenstock, L. (2003). The Environment as a Cornerstone of Public Health, *Environmental Health Perspectives, 111 (7),* A376 – A377.

Sanderson, E. W. (2010). 'The Human Foot Print and the Last of the Wild'. *Nature* 417:64 - 75.

Shelton, T. (1991). Interpreting Drinking Water Quality Analysis: What do the Number Mean? New Brunswick, NJ: Rutgers Cooperate Extension, 13 – 28.

Steel, G. D. and Torrie, J. H. (1980). Procedures of Statistics: A Biometric Approach. 2nded, McGraw-Hill Book Company, New York.

Tracy, C. and Nicholas, H. (1992). 'The Politics of Industrial Agriculture'. *Nature, 1984, Vol. 301,* 24.

United States Geological Survey (1998). Study and Interpretation of the Chemical Characteristics of Natural Water Supply. National Research Council, Washington, DC,1618.

World Health Organisation (WHO) (2000). The International Standard for Drinking Water Quality, WHO, General, 346 – 355.

World Health Organization (WHO) (2011). *International Standards for Drinking Water Qualities*, *3rd ed*. WHO, Geneva.

World Health Organization (WHO), (2010b). The World Health Report – Health Systems Financing: The Path to Universal Coverage. Retrieved from http://www.who.int/entity/whr/2010/whr10-en.pdf