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# Effective Effluent Waste Management in Shell Bonny Terminal and Pollution Control in Bonny River

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## Abstract

The paper discussed effective effluent waste management in Shell Bonny terminal and pollution control in bonny river. It defines effective effluent waste management as the treatment and discharge of industrial wastewaters in such a manner that the physical, chemical and biological composition of the receiving water body is not altered. The research question addressed the extent of the relationship between effective effluent waste management in Shell Bonny terminal and reduced pollution of bonny river/conflicts with host communities. The place of study is Shell Bonny terminal while the duration of study is between December 2014 and November 2015. A descriptive research design was used in executing the study using 370 randomly selected respondents from a population of 3700 employees for questionnaire administration. The sample size of 370 was judgmentally determined from 10% of the population size. The core aspect of the study is the use of cross sectional survey research design in generating the required primary data. Data collected were analyzed using descriptive and inferential statistics. Results from the data analysis indicated that significant relationship exists between effective effluent waste management and reduced pollution of bonny river/conflicts with host communities. The research therefore recommends among others: regular maintenance of the emulsion treatment plant, consistent commitment of management/employees to effective effluent waste management, training of employees on latest effluent waste management techniques, provision of incentives for good effluent waste management practices, regular interaction with host communities to identify and resolve potential areas of conflict.

## Keywords

Effluent Waste, Pollution Control, Bonny River, Community Conflict, Shell Bonny Terminal

## 1. Introduction

### 1.1. Background of the Study

Shell bonny terminal is a crude oil storage deport of Shell Petroleum Development Company of Nigeria. It is located in Bonny Island which is 48km south east of Port-Harcourt. It receives crude oil via pipelines from various oil fields and flow stations in the Eastern Delta region of Nigeria. Export of crude oil from the terminal occurs every 2 days, to allow sufficient time for enough crude to be filtered in the terminal's 23 tanks, a process that takes about 30 hours. In addition to a 23-km pipeline to the offshore crude loading platform, the bonny terminal is linked to the 150,000 b/d refinery at Port Harcourt by a 50-km pipeline that feeds it with crude oil for refining, though the latter line is currently inactive (SPDC, 2014). The terminal dehydrates and stores crude oil in metal storage tanks for onward transmission to the offshore loading platform for export. During the process of crude oil collection, dehydration, storage and transmission, wastes (emulsion, sludge and produce water) are generated and treated via an emulsion treatment plant while the by-products are discharged into the bonny river as industrial waste waters or effluents.

Industrial effluents entering a water body like the bonny river represent a heavy source of environmental pollution in

Nigerian rivers because it affects both the water quality as well as the microbial and aquatic flora. With competing demands on limited water resources, awareness of the issues involved in water pollution, has led to considerable public debate about the environmental effects of industrial effluents discharged into aquatic environments. Industrial effluents are characterized by their abnormal turbidity, conductivity, chemical oxygen demand (COD), total suspended solids (TSS), biological oxygen demand (BOD), and total hardness. Industrial effluents containing high concentration of microbial nutrients would obviously promote an after-growth of significantly high coliform types and other microbial forms.

Industrial effluents rich in decomposable organic matter, has emerged as a major cause of organic pollution of natural water bodies in developing and densely populated countries like Nigeria. Estuaries and inland water bodies, which are the major sources of drinking water and economic activities in Nigeria, are often contaminated by the activities of industrial establishments (Sangodoyin, 1995). River systems are the primary means of disposal of effluents, from industries that are near them. These effluents have a great deal of influence on the receiving water body because it may alter its physical, chemical and biological composition (Sangodoyin, 1991).

Industries are the major sources of pollution in all environments. Based on the type of industry, various levels of pollutants can be discharged into the environment directly or indirectly through public sewer lines. Wastewater from industries includes: employees 'sanitary waste, process wastes, wash waters and relatively uncontaminated water from heating and cooling operations (Glyn and Gary, 1996). High levels of pollutants in river water systems causes an increase in biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), toxic metals and fecal coliform, thus making such water body unsuitable for aquatic life. Industrial wastewaters range from high biochemical oxygen demand (BOD) to biodegradable wastes.

Unfortunately, there are very few water quality studies for most African inland waters. In general, the available data come from scattered investigations, which were carried out by individuals and by very few scientific projects concerned with African waters. Few reviews exist on the state of pollution of African inland waters (Dejoux et al, 1981, Egborge et al, 1999 & Burgis, 1987). With competing demands on limited water resources, industrial pollution remains one of the major problems facing Nigerian cities. As societies throughout the world become more aware of the issues involved in water pollution, there has been considerable public debate about environmental effects of effluents discharged into aquatic environments (Calamari, 1985). Effluent discharge practices in Nigeria are yet too crude and the society is in danger, especially in the industrialized part of the cities. The Federal Environmental Protection Agency (FEPA) established to check these environmental abuses has had little or no impact on pollution control in our cities (Ezeronye and Amogu, 1998). It is against this background that it becomes pertinent to embark on a study that examines effective effluent waste management in Shell Bonny terminal and pollution control in bonny river.

## 1.2. Statement of the Problem

Industrial effluents are the main source of direct and often continuous input of pollutants into aquatic ecosystems with long-term implications on ecosystem functioning including changes in food availability and an extreme threat to the self-regulating capacity of the biosphere. The industrial effluents of the bonny terminal that are discharged into the bonny river include heavy metals, polychlorinated biphenyls (PCBs), dioxins, poly-aromatic hydrocarbons (PAHs), phenolic compounds and microorganisms (Fakayode, 2005, Davies & Gasse, 1988 and Nubi, et al, 2008). The bonny terminal effluents containing high concentration of microbial nutrients would obviously promote an after growth of significantly high coliform types and other microbial forms. Some heavy metals contained in these effluents have been found to be carcinogenic while others are poisonous depending on their dosage and duration of exposure. Undoubtedly, wastewaters from industries and residential areas discharged into another environment without suitable treatment could disturb the ecological balance of such an environment (Botkin and Kelly, 1998).

However, the rush by African countries to industrialize has resulted in discharge of partially treated or raw wastes into the surrounding bodies of water since the development of treatment facilities cannot keep pace with the rate at which the wastes are generated by the industries (Nwachukwu et al, 1989). Many bodies of water in Nigeria including the bonny river experience seasonal fluctuations, leading to a higher concentration of pollutants during the dry season when effluents are least diluted (Kanu et al, 2006).

The characteristics of the bonny terminal effluent wastes provide basic information about the integrity of the aquatic habitat into which they are discharged. Most of these effluent wastes pose inestimable harm to the aquatic environment of which the microbial entity is the most adversely affected. Although, the physicochemical analysis of the bonny terminal effluent wastes indicate conformance with the recommended FEPA(Federal Environmental Protection Agency, 1991) guidelines, however, exceptions occur in the total dissolved solids (TDS) and Nitrate ($NO_{3-}$) contents. These are found to be very high in most of the bonny terminal effluent wastes sampled coupled with a high pH index. Also, an important index of the bonny terminal effluent wastes is the oxygen function measured in terms of chemical oxygen demand (COD), and biological oxygen demand (BOD5), the nutrient status are measured in terms of nitrogen and phosphorus content while other important quality parameters include temperature and total suspended solids (Ezenobi & Okpokwasili, 2004). Generally, the bonny terminal effluent wastes are characterized by their abnormal turbidity, conductivity, chemical oxygen demand (COD); total suspended solids (TSS) and total hardness. The effluent total hardness concentrations of the bonny terminal emulsion treatment plant were found to be greater than the influents. Hence, the bonny coastal residential environment is always under considerable stress due to the prevailing harsh environmental conditions, especially high temperature and salinity, restricted benthic fauna diversity and overall development of a fragile intertidal ecosystem.

### 1.3. Research Objectives

The objectives of the research are as follows:

(1). To determine the extent of the relationship between effective effluent waste management in Shell Bonny terminal and reduced pollution of bonny river.

(2). To determine the extent of the relationship between effective effluent waste management in Shell Bonny terminal and reduced conflicts with host communities.

### 1.4. Research Questions

Despite the adequacies of the present effluent waste treatment plant in Shell bonny terminal, the various milestones recorded by the terminal in terms of consistent certification of its effluent waste management system by both local and international organizations would not have been possible without an effective effluent waste management plant (emulsion treatment plant) thus prompting the following research questions:

(1). Does any significant relationship exist between effective effluent waste management in Shell Bonny terminal and reduced pollution of bonny river?

(2). Does any significant relationship exist between effective effluent waste management in Shell Bonny terminal and reduced conflicts with host communities?

### 1.5. Research Hypotheses

In view of the above research questions, the following null hypotheses were formulated:

1 $H_O$: There is no significant relationship between effective effluent waste management in Shell Bonny terminal and reduced pollution of bonny river.

2 $H_O$: There is no significant relationship between effective effluent waste management in Shell Bonny terminal and reduced conflicts with host communities.

### 1.6. Literature Review

All over the world, environmental pollution is an issue of great concern because of what the environment is to human survival and indeed, the survival of the earth itself. Pollution had always been misused for contamination which can be defined as the presence of elevated concentrations of a substance in the air, water, soil or any other such thing not necessarily resulting in a deleterious effect.

Aquatic pollution, therefore, is the direct or indirect introduction of substances into the aquatic environment, which affect human health and water quality.

Pollution is not merely the addition of a substance to the aquatic ecosystem, but its addition at a rate faster than the ecosystem can accommodate. Pollutants are not only chemicals. To be a pollutant, a material has to be potentially harmful to life. Chemicals released into the rivers and seas such as Pb, Cu, Zn, Hg, and CN will cause the death of fish, algae and lesions in human beings even at very low concentrations. Effluent from industries is a major source of environmental pollution. The discharge of wastewater into surface waters and the resultant deleterious changes in water ecology have been reported by several researchers (Odokuma & Okpokwasili, 1993 and Agbagwa & Okpokwasili, 2011) who also expressed concern over human health and the possible accumulation of human enteric pathogenic microorganisms by aquatic organisms.

Incidences of water-borne diseases in rural areas of developing countries leading to millions of deaths have been reported (United Nations University, 1983). Some of these deaths have been traced to the use of waters grossly polluted by untreated waste (De Silva, Karunatileka & Thiemann, 1988.). Akpata and Ekundayo (1978) also reported an increase in the number of total coliforms and of *E. coli* in particular when faeces were added to the Lagos lagoon. Okoronkwo &Odeyemi (1985) reported a similar trend in the pollution of a stream by wastewater from a sewage lagoon. Egborge & Benka-Coker, (1986), also reported relatively higher faecal coliform loads at stations on Warri River in Nigeria that received faecal matter from slaughterhouses and raw sewage from human sources. Idowu, et al. (2011) also reported the same trend of contamination of well water with pathogenic enteric organisms in Sagamu Southwestern Nigeria.

In Nigeria, pollution of river water takes place at various centers of industrialization, chiefly at Lagos, Abeokuta, Ibadan, Warri, Port Harcourt, Aba, Kano etc. Industries generate a significant quantity of wastewater which are discharged into rivers and lakes (Adedeji, et al, 2011). Industrial discharges generally contain organic substances, solids and mineral acids. A study on water quality of Ogun River, in which industrial effluents from Lagos and Abeokuta were discharged, was conducted, and it was reported that the level of turbidity, oil and grease, faecal coliform and iron were very high in all the sampling sites (Jaji, et al, 2007). The characteristics of selected effluents from industries in Benin City, Nigeria, were analyzed and it was reported that the concentration of pollutants in the effluents discharge was on the high side, exceeding the maximum recommended limits (Goalie&Okhagbuzo, 2010). Industrial effluents contain toxic and hazardous substances that are detrimental to both aquatic life and human health. These include heavy metals such as lead, chromium and mercury, and toxic organic chemicals such as pesticides, polychlorinated biphenyls (PCBs) polyaromatic hydrocarbons (PAHs), petrochemicals and phenolic compounds. Improper disposal of industrial effluents has resulted in colored, murky, odorous and unwholesome surface waters, deaths of fish and loss of recreational amenities.

Neff in 1987 noted that there are more hazardous substances in produced water from gas and condensate platforms than from oil platforms. Often times, there are concentrations of Barium, Beryllium, Cadmium, Chromium, Copper, Iron, Lead, Nickel, Silver, Zinc, and small amounts of natural radioactive materials. In 1992, Jacobs et al., presented results of a study conducted on produced water from Shell operated oil and gas fields in the North Sea. They observed that produced waters discharged from gas and condensate platforms are far more toxic than the produced waters discharged from oil platforms. Cox (1992) also presented similar observations made in Alberta. In 1994 the London-based International Exploration and Production Forum (E and P Forum) published a detailed report on the fate and effects in marine environment of produced water in the North Sea. The average oil content of produced water discharged in 1991 alone from all North Sea production platforms was estimated at 34 mg/l amounting to discharge of 160 million cubic metres, 95% of which was from oil installations and 5% from gas. The discharges were estimated to contain about 52,600 tonnes of organic compounds and 1,000 tonnes of heavy metals.

In 1998, Cline noted that produced waters from petroleum production operations are in most cases, more saline than sea water. Smith, et al. (1998) has also confirmed the negative effects of produced waters on the Indonesian environment. However, studies have shown that where there is effective dilution, acute toxic effects of effluent water are not expected to be found beyond 50m from the discharge point (Johnsen et al., 2004). Durrell et al. (2006) reported that oil companies operating in Norway have since the mid-1990s tried to develop efficient monitoring methods for discharged water. In Nigeria, Oboh, et al. (2009) have presented results of experiments conducted on produced waters from an oil field in Nigeria and noted that the discharged waters had high metal ions and total hydrocarbon concentrations which could be reduced by further treatment with lorffa cylindrical. Knudsen et al. (2010) however suggested that fresh water dilution of formation waters in the Niger Delta before disposal could be very effective. Ekins et al. (2005) demonstrated that produced water discharges in near shore environment in the Niger Delta leads to substantial accumulation of hydrocarbons and microorganisms up to 500 m from discharge points.

## 1.7. Conceptual Framework

Industrial wastewaters entering a water body represent a heavy source of environmental pollution in Nigerian rivers. It affects both the water quality as well as the microbial and aquatic flora. With competing demands on limited water resources, awareness of the issues involved in water pollution, has led to considerable public debate about the environmental effects of industrial effluents discharged into aquatic environments. Industrial effluents are characterized by their abnormal turbidity, conductivity, chemical oxygen demand (COD), total suspended solids (TSS), biological oxygen demand (BOD), and total hardness. Industrial wastes containing high concentration of microbial nutrients would obviously promote an after-growth of significantly high coliform types and other microbial forms. Effective effluent waste management is the treatment and discharge of industrial wastewaters in such a manner that the physical, chemical and biological composition of the receiving water body is not altered.

Industrial effluents are a main source of direct and often continuous input of pollutants into aquatic ecosystems with long-term implications on ecosystem functioning including changes in food availability and an extreme threat to the self-regulating capacity of the biosphere. These industrial discharge or wastes include heavy metals, pesticides, polychlorinated biphenyls (PCBs), dioxins, poly-aromatic hydrocarbons (PAHs), petrochemicals, phenolic compounds and microorganisms (Fakayode, 2005, Davies &Gasse, 1988 and Nubi, et al, 2008). These wastes are usually discharged into water bodies and the cumulative hazardous effects it has on the environment have received much attention. Industrial wastes containing high concentration of microbial nutrients would obviously promote an after-growth of significantly high coliform types and other microbial forms. Some heavy metals contained in these effluents have been found to be carcinogenic while other chemicals equally present are poisonous depending on the dose and duration of exposure.

Industrial effluents are characterized by their abnormal turbidity, conductivity, chemical oxygen demand (COD); total suspended solids (TSS) and total hardness. The effluent total hardness concentrations of a chemical-biological treatment plant were found greater than the influents. The results are presented in terms of the relative flux as a function of time related to hydrodynamic conditions and pollution characteristics of wastewater (Gunfowokan & Fakankun, 1998). According to Kanu & Achi, (2011), the dominant soluble nitrogen form in a typical industrial effluent is NO3 -N followed by Kjeldahl-N, NO1 -N and non-ionic ammonia while mean values of NO3 -N, NO2-N, Kjeldahl-N and non-ionic ammonia ranged from 0.50 to 2.37 mg L-1, 0.022 to 0.084 mg L-1, 0.33 to 0.99 mg L-1 and 0.007 to 0.092 mg L respectively. Mean values of P-PO4 at most sampling sites were higher than 0.1 mg L for subject to eutrophication and the characteristics of rivers and the nearby soils near them affect the equilibrium concentrations of N and P between the soil and the overlying water Industrial effluents are also known to exhibit toxicity toward different aquatic organisms.

The coastal residential environment in any industrial effluent site is always under considerable stress due to the prevailing harsh environmental conditions, especially high temperature and salinity, restricted benthic fauna diversity and overall development of a fragile intertidal ecosystem. The fauna inhabiting the intertidal zone is most likely dominated by a few species probably living at their limit of tolerance (Awomeso et al, 2010). Organic pollution is always evident and the pollution is made worse by land-based sources such as the occasional discharge of raw sewage through storm water outlets, and industrial effluents from refineries, oil terminals, and petrochemical plants (Adekunle & Eniola, 2008).

## 2. Method

*Research Design*

The scope of this research is limited to the contractor staff, contract staff and direct staff working at shell bonny terminal. It is assumed that responses obtained from the sample respondents would be representative of the opinions of all categories of employees at the terminal on their perception of effective effluent waste management in Shell Bonny terminal and pollution control in bonny river. The duration of study is between December, 2014 and November, 2015. The core aspect of the study is the use of cross sectional survey research design in generating the required primary data. A sample of 370 randomly selected respondents from a population of 3,700 shell bonny terminal employees consisting of 1,850 contractor staff, 1,480 contract staff and 370 direct staff at shell bonny terminal was used for questionnaire administration. The sample size of 370 was judgmentally determined from 10% of the population size. The sample respondents were selected using shuffling of cards method (without replacement) in which all the names of the three categories of employees' were each separately written on small cards and the name at the topmost of each of the three group of cards was selected each time, the cards were shuffled until all the sample respondents were selected.

Data collected were analyzed using descriptive and inferential statistics. The questionnaire was designed to obtain a fair representation of the opinions of 370 sample respondents(185 contractor staff, 148 contract staff and 37 direct staff) using a four-point Likert type scale. The questionnaire responses of the sample respondents were presented using tables while formulated hypotheses were tested using analysis of variance (ANOVA). A total of 370 copies of the questionnaire were administered, collected and used for the analysis.

## 3. Results and Discussion

### 3.1. Distribution of Responses on Research Questions

#### 3.1.1. Question Number 1

Does any significant relationship exist between effective effluent waste management in Shell Bonny terminal and reduced pollution of bonny river?

Table 1 shows that questions: 1, 2, 3, 4, and 5 with varying mean scores of 3.00, 2.84, 2.78, 2.73 and 3.03 were above the weighted average of 2.5. The table further revealed a grand mean score of 2.88 indicating a strong evidence of the existence of a significant relationship between effective effluent waste management in Shell Bonny terminal and reduced pollution of bonny river. This is supported by the studies of Johnsen et al., (2000, 2004) which concludes that where there is effective dilution, acute toxic effects of effluent water are not expected to be found beyond 50m from the discharge point. This conclusion is also supported by the observation of Oboh, et al. (2009) that discharged waters with high concentration of metal ions and hydrocarbon could be reduced by further treatment with lorffa cylindrical.

$$\text{Mean Score} = \frac{4n4+3n3+2n2+1n1}{(n4+ n3+ n2+n1)}$$

Where n1, n2, n3 and n4 are the respective number of responses obtained from each of the four options provided while1, 2, 3 and 4 respectively represent the weights (SA (4), A (3), D (2) & SD (1) attached to each of the four options.

***Table 1.*** *Mean responses on the relationship between effective effluent waste management in Shell Bonny terminal and reduced pollution of bonny river (n=370).*

| S/No. | Research Questions | SA(4) | A(3) | D(2) | SD(1) | Total Responses | Mean Score |
|---|---|---|---|---|---|---|---|
| 1. | Does effective effluent waste management in Shell Bonny terminal reduce the volume of effluent waste discharged in bonny river? | 150<br>600 | 100<br>300 | 90<br>180 | 30<br>30 | 1110 | 3.00 |
| 2. | Does effective effluent waste management in Shell Bonny terminal reduce the level of BOD, COD, TDS & TSS discharged in bonny river? | 130<br>520 | 100<br>300 | 90<br>180 | 50<br>50 | 1050 | 2.84 |
| 3. | Does effective effluent waste management in Shell Bonny terminal reduce the microbial concentration of bonny river? | 120<br>480 | 100<br>300 | 100<br>200 | 50<br>50 | 1030 | 2.78 |
| 4. | Does effective effluent waste management in Shell Bonny terminal reduce the turbidity, conductivity, and total hardness of bonny river? | 130<br>520 | 80<br>240 | 90<br>180 | 70<br>70 | 1010 | 2.73 |
| 5. | Does effective effluent waste management in Shell Bonny terminal reduce the level of toxic metals and fecal coliform discharged in bonny river? | 160<br>640 | 100<br>300 | 70<br>140 | 40<br>40 | 1120 | 3.03 |
| | Grand Mean | | | | | | 2.88 |

Source: Field Survey, 2015.

#### 3.1.2. Question Number 2

Does any significant relationship exist between effective effluent waste management in Shell Bonny terminal and reduced conflicts with host communities?

Table 2 shows that questions: 6, 7, 8, 9, and 10 with mean scores of 2.70, 2.97, 2.84, 2.68 and 3.00 were above the weighted average of 2.50. The grand mean of 2.84 shows that there is a strong evidence of a significant relationship between effective effluent waste management in Shell Bonny terminal and reduced conflicts with host communities.

***Table 2.*** *Mean responses on the relationship between effective effluent waste management in Shell Bonny terminal and reduced conflicts with host communities (n=370).*

| S/No. | Research Questions | SA(4) | A (3) | D(2) | SD(1) | Total Responses | Mean Score |
|---|---|---|---|---|---|---|---|
| 6. | Does effective effluent waste management in Shell Bonny terminal reduce the damage to the host communities' aquatic ecosystem? | 120<br>480 | 90<br>270 | 90<br>180 | 70<br>70 | 1000 | 2.70 |
| 7. | Does effective effluent waste management in Shell Bonny terminal reduce the damage to the host communities' occupation? | 150<br>600 | 100<br>300 | 80<br>160 | 40<br>40 | 1100 | 2.97 |
| 8. | Does effective effluent waste management in Shell Bonny terminal reduce the damage to the host communities' flora and fauna? | 130<br>520 | 100<br>300 | 90<br>180 | 50<br>50 | 1050 | 2.84 |
| 9 | Does effective effluent waste management in Shell Bonny terminal reduce the damage to the host communities' source of water supply? | 110<br>440 | 100<br>300 | 90<br>180 | 70<br>70 | 990 | 2.68 |
| 10 | Does effective effluent waste management in Shell Bonny terminal reduce the damage to the host communities' fish farms? | 160<br>640 | 90<br>270 | 80<br>160 | 40<br>40 | 1110 | 3.00 |
| | Grand Mean | | | | | | 2.84 |

Source: Field Survey, 2015.

## 3.2. Test of the First Hypothesis

$H_o$: There is no significant relationship between effective effluent waste management in Shell Bonny terminal and reduced pollution of bonny river.

$H_I$: There is a significant relationship between effective effluent waste management in Shell Bonny terminal and reduced pollution of bonny river.

***Table 3.*** *Computation of Statistical Variables on the First Hypothesis from table 1.*

| S/No. | Strongly Agree | | Agree | | Disagree | | Strongly Disagree | |
|---|---|---|---|---|---|---|---|---|
| | X | X² | X | X2 | X | X² | X | X² |
| 1 | 150 | 22500 | 100 | 10000 | 90 | 8100 | 30 | 900 |
| 2 | 130 | 16900 | 100 | 10000 | 90 | 8100 | 50 | 2500 |
| 3 | 120 | 14400 | 100 | 10000 | 100 | 10000 | 50 | 2500 |
| 4 | 130 | 16900 | 80 | 6400 | 90 | 8100 | 70 | 4900 |
| 5 | 160 | 25600 | 100 | 10000 | 70 | 4900 | 40 | 1600 |
| Totals | 690 | 96300 | 480 | 46400 | 440 | 39200 | 240 | 12400 |

Source: Survey Data, 2015.

Calculation of total sum of squares ($SS_T$)

$$SS_T = \sum_{i=1}^{C} \sum_{j=1}^{n_1} (X_{ij} - \bar{\bar{X}}_i)^2$$

$$\sum X\,2 = 96300 + 46400 + 39200 + 12400 = 194300$$

$$\frac{\sum X^2}{N} = \frac{(690+480+440+240)^2}{20} = 171125$$

$$SS_T = 194300 - 171125 = 23175$$

$$SS_T = 23175$$

Calculation of between group sum of squares ($SS_B$)

$$SS_B = \sum_{i=1}^{C} n_i \quad (\bar{X} - \bar{\bar{X}})^2$$

$$\frac{\sum X^2}{N} = \frac{(690)^2}{5} + \frac{(480)^2}{5} + \frac{(440)^2}{5} + \frac{(240)^2}{5}$$

$$= 95220 + 46080 + 38720 + 11520 = 191540$$

$$\frac{\sum X^2}{N} = \frac{(690+480+440+240)^2}{20} = 171125$$

$$SS_B = 191540 - 171125 = 20415$$

$$SS_B = 20415$$

Calculation of within group sum of squares (SSw)

$SSw = \sum_{i=1}^{C} \sum_{j=1}^{n_i} (X_{ij} - \bar{X})^2$ or $SS_W = SS_T - SS_B$

$SS_T - SS_B = 23175 - 20415 = 2760$

$SS_W = 2760$

Calculation degrees of freedom

$SS_T$ df = N – 1 = 20 – 1 = 19

$SS_B$ df = n – 1 = 4 -1 = 3

$SS_W$ df = n – 1 + n – 1 + n – 1 + n – 1 = 4n - 4 = 4 (5) – 4 = 20 – 4 = 16

Calculation of Variances

$$\text{Between group variance } (S_B^2) = \frac{\text{Between group sum of squares (SSB)}}{\text{Between group degree of freedom}}$$

$$S_B^2 = \frac{\sum_{i=1}^{C} n_i (\bar{X_i} - \bar{\bar{X_i}})^2}{C-1}$$

$$S_B^2 = \frac{20415}{3} = 6805$$

$$\text{Within group variance } (S_W^2) = \frac{\text{Within group sum of squares (SSW)}}{\text{Within group degree of freedom}}$$

$$S_W^2 = \frac{\sum_{i=1}^{C} \sum_{j=1}^{n_1} (X_{ij} - \bar{X}i)^2}{n-c}$$

$$S_W^2 = \frac{2760}{16} = 172.5$$

$$\text{F-value} = F_{df_{1,df_2}} = \frac{S_{B^2}}{S_{W^2}} = \frac{\text{Between group variance}}{\text{Within group variance}} = \frac{6805}{172.5} = 39.45$$

Table 4 shows that calculated F-Value of 39.45 resulted from the relationship between effective effluent waste management in Shell Bonny terminal and reduced pollution of bonny river. This calculated F-Value is significant since it is greater than the critical F-Value of 5.29 given 3/16 degree of freedom at 0.01 level of significance. Hence, the null hypothesis is rejected while the alternative is accepted. This shows that there is a significant relationship between effective effluent waste management in Shell Bonny terminal and reduced pollution of bonny river.

***Table 4.*** *Computation of Analysis of Variance on the relationship between effective effluent waste management in Shell Bonny terminal and reduced pollution of bonny river.*

| Source of variance | Sum of squares | Degree of freedom | Mean sum of squares | Calculated F-value | Table critical F- value | Decision |
|---|---|---|---|---|---|---|
| Between groups | 20415 | 3 | 6805 | 4. 39.45 | 5.29 | $H_{0: \text{Rejected}}$ |
| Within group | 2760 | 16 | 172.5 | | | |
| Total | 23175 | 19 | | | | |

Source: Statistical Computation and Table 3.

### 3.3. Test of the Second Hypothesis

$H_o$: There is no significant relationship between effective effluent waste management in Shell Bonny terminal and reduced conflicts with host communities.

$H_1$: There is a significant relationship between effective effluent waste management in Shell Bonny terminal and reduced conflicts with host communities.

***Table 5.*** *Computation of Statistical Variables on the second Hypothesis from table 2.*

| S/No. | Strongly Agree | | Agree | | Disagree | | Strongly Disagree | |
|---|---|---|---|---|---|---|---|---|
| | X | X² | X | X² | X | X² | X | X² |
| 6 | 120 | 14400 | 90 | 8100 | 90 | 8100 | 70 | 4900 |
| 7 | 150 | 22500 | 100 | 10000 | 80 | 6400 | 40 | 1600 |
| 8 | 130 | 16900 | 100 | 10000 | 90 | 8100 | 50 | 2500 |
| 9 | 110 | 12100 | 100 | 10000 | 90 | 8100 | 70 | 4900 |
| 10 | 160 | 25600 | 90 | 8100 | 80 | 6400 | 40 | 1600 |
| Totals | 670 | 91500 | 480 | 46200 | 430 | 37100 | 270 | 15500 |

Source: Survey Data, 2015.

Calculation of total sum of squares ($SS_T$)

$$SS_T = \sum_{i=1}^{C}\sum_{j=1}^{n_1} (X_{ij} - \bar{\bar{X}}_i)^2$$

$$\sum_X 2 = 91500 + 46200+37100+15500=190300$$

$$\frac{\sum_{X^2}}{N} = \frac{(670+480+430+270)^2}{20} = 171125$$

$$SS_T = 190300-171125 = 19175$$

$$SS_T = 19175$$

Calculation of between group sum of squares ($SS_B$)

$$SS_B = \sum_{i=1}^{C} n_i \quad (\bar{X} - \bar{\bar{X}})^2$$

$$\frac{\sum_{X^2}}{N} = \frac{(670)^2}{5} + \frac{(480)^2}{5} + \frac{(430)^2}{5} + \frac{(270)^2}{5}$$

$$= 89780+ 46080+ 36980 + 14580 = 187420$$

$$\frac{\sum_{X^2}}{N} = \frac{(670+ 480 + 430 +270)^2}{20} = 171125$$

$$SS_B = 187420 - 171125= 16295$$

$$SS_B = 16295$$

Calculation of within group sum of squares (SSw)

$SSw = \sum_{i=1}^{C}\sum_{j=1}^{n_i}(X_{ij} - \bar{X})^2$ or $SS_W = SS_T - SS_B$

$SS_W = SS_T - SS_B = 19175 - 16295= 2880$

$SS_W = 2880$

Calculation of Degrees of Freedom

$SS_T$ df = N – 1 = 20 – 1 = 19

$SS_B$ df = n – 1 = 4 -1 = 3

$SS_W$ df = n – 1 + n – 1 + n – 1 + n – 1 = 4n - 4 = 4 (5) – 4 = 20 – 4 = 16

Calculation of Variances

$$\text{Between group variance } (S_B^2) = \frac{\text{Between group sum of squares (SSB)}}{\text{Between group degree of freedom}}$$

$$S_B^2 = \frac{\sum_{i=1}^{C} n_i(\bar{X_i} - \bar{\bar{X_i}})^2}{C-1}$$

$$S_B^2 = \frac{16295}{3} = 5431.67$$

$$\text{Within group variance } (S_W^2) = \frac{\text{Within group sum of squares (SSW)}}{\text{Within group degree of freedom}}$$

$$S_W^2 = \frac{\sum_{i=1}^{C}\sum_{j=1}^{n_1} (X_{ij} - \bar{X}i)^2}{n-c}$$

$$S_W^2 = \frac{2880}{16} = 180$$

$$\text{F-value} = F_{df_{1,}df_2} = \frac{S_{B^2}}{S_{W^2}} = \frac{\text{Between group variance}}{\text{Within group variance}} = \frac{5431.67}{180} = 30.18$$

Table 6 shows that calculated F-Value of 30.18 resulted from the relationship between effective effluent waste management in Shell Bonny terminal and reduced conflicts with host communities. This calculated F-Value is significant since it is greater than the critical F-Value of 5.29 given 3/16 degree of freedom at 0.01 level of significance. Hence, the null hypothesis is rejected while the alternative is accepted. This shows that there is a significant relationship between effective effluent waste management in Shell Bonny terminal and reduced conflicts with host communities.

***Table 6.*** *Computation of Analysis of Variance on the relationship between effective effluent waste management in Shell Bonny terminal and reduced conflicts with host communities.*

| Source of variance | sum of square | Degree of freedom | Mean sum of square | Calculate F-value | Table critical F-value | Decision |
|---|---|---|---|---|---|---|
| Between group | 16295 | 3 | 5431.67 | 30.18 | 5.29 | $H_{o: Rejected}$ |
| Within group | 2880 | 16 | 180 | | | |
| Total | 19175 | 19 | | | | |

Source: Statistical Computation and Table 5

## 4. Conclusion and Recommendations

The paper discussed effective effluent waste management in Shell Bonny terminal and pollution control in bonny river. It assumes that effective effluent waste management in Shell Bonny terminal can reduce the pollution of bonny river. The three major findings of the research are as follows:

- Effective effluent waste management in Shell Bonny terminal reduce the volume of effluent waste discharged into bonny river.
- There is a significant relationship between effective effluent waste management in Shell Bonny terminal and reduced pollution of bonny river.
- There is a significant relationship between effective effluent waste management in Shell Bonny terminal and reduced conflicts with host communities.

Arising from the findings of this paper, it is suggested that the management of Shell Bonny terminal should take the following measures to improve their current effluent waste management practices:

(1). Regular maintenance of the emulsion treatment plant: This will ensure efficient and continuous treatment of effluent waste before discharge into the bonny river to minimize negative impact on the aquatic ecosystem.

(2). Consistent commitment of management/employees to effective effluent waste management: This will ensure that effluent waste pollution control is given top priority by all and sundry in shell bonny terminal.

(3). Training of employees on latest effluent waste management techniques: This will ensure that employees are equipped with the latest knowledge/techniques of handling effluent waste in line with current best practices to avert aquatic pollution.

(4). Provision of incentives for good effluent waste management practices: Employees should be periodically rewarded for good effluent waste management practices to ensure sustenance of such practices I n their day to day operations.

(5). Regular interaction with host communities to identify and resolve potential areas of conflict: This will ensure that potential areas of conflict in operational activities are quickly identified and resolved.

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