Quality Assessment of Effluent from A Typical Food Processing Industry in Port Harcourt

[a*] Brume J. Egere; [b] Anthony Okhifo

[a] Chemical Engineering Department; University of Port Harcourt, Rivers state, Nigeria.

[b] Chemistry Department, Maritime University, Okerenkoko, Delta state, Nigeria.

DOI: https://dx.doi.org/10.51244/IJRSI.2025.1210000316

Received: 02 October 2025; Accepted: 08 October 2025; Published: 21 November 2025

ABSTRACT

The study investigated the quality of effluent discharge from a food industry in a Port Harcourt suburb in Rivers State, Nigeria. The food industry is engaged in noodle pasta and vegetable oil production. The discharged effluent is channeled to a neighboring marshland about 220m away from the factory. The purpose of this study is to analyze the critical parameters of the food industry effluent in order to determine its pollution potential, and also assess its possible effect on the ecosystem. Standard test methods such as the APHA (American Public Health Association) and ASTM (American Society for Testing and Materials) methods were used to conduct the tests. Parameters examined were pH, conductivity, BOD, COD, SO_4^{2-}, Cl^-, PO_4^{3-}, Oil and grease, NO_3^{2-}, Turbidity, Fe, Zn, Pb, Cu, Cr, Cd, Ni. The data obtained from these analyses were used in assessing compliance with regulatory limits and identifying specific pollutants requiring targeted remediation. High values of oil and grease content were recorded both in the effluent (700.5±53.2mg/l) and in the recipient soil (3107±137mg/l) which were extremely above the WHO/NESREA acceptable limit of 10mg/l. The high values of the oil and grease were attributed to the absence of oil-water separator in the effluent treatment process. The mean values of BOD (34.42±9.7mg/l) and COD (153.4±42.4mg/l) were slightly higher than the WHO/NESREA acceptable limit of 30 and 150mg/l respectively. The control was however within the acceptable limit with recorded values as 28.0±5.4mg/l and 110±24.6 mg/l respectively. This indicates the presence of high organic load and a proof that the recipient environment is impacted. All the heavy metals tested in the effluent except Fe (0.77±0.25mg/l) were below the WHO/NESREA acceptable limit of $\leq$0.3mg/l. The discharged effluents were generally acidic which was indicated by low pH values with a mean of 5.09±0.6. Turbidity mean values was 40.3±8.5 NTU and these were above the regulatory limit of 5-10NTU. The general physical state of the effluent was turbid with whitish suspension or translucent with oily suspension on the surface. This indicated a poor treatment of the effluent. Effluent monitoring and treatment are necessary if the environment will be spared of the dangers. This paper, therefore, recommends that the food processing industry should effectively treat its effluents before disposal.

INTRODUCTION

The food processing industry plays a significant role in the economy of any nation because its operations enables the conversion of raw agricultural products into finished food items with improved nutritional, textural and shelf values. The production activity however is not without the consequent problem of environmental pollution (Olaniyi et. al.,2012; Omuku et. al.,2024).

Over the years, the food processing industries have generated wastes which were considered less polluting in comparison with the oil industry effluents. The consequences of focusing on economic growth at the expense of environmental sustainability calls for serious concern (Tommaso, 2011; Asgharnejad et. al., 2021).

The food processing sector in Nigeria is of national significance owing to the number of industries engaged in food production activities to meet the population needs (Owalude et. al., 2021). The implication of this is the generation of large volumes of wastes which results in environmental pollution (Tommaso, 2011). The large quantity of wastewater from food processing industries largely constitutes nuisance to the environment when discharged without compliance to regulatory standards (Ribeiro & Naval, 2021; Owalude et. al., 2021).

The food industry generates effluents which are of significant environmental concern because of the large amount of organic content and the large volume of water used during processing (Tommaso, 2011; Joudah & Racoviteau, 2019). Human health and the aquatic ecosystem are subjected to considerable risks due to exposure to these discharged effluents that contain high COD, BOD and non-biodegradable pollutants (Mostafaie et al, 2021; Mangotra & Singh, 2024).

A thorough evaluation of the physiochemical characteristics of effluent is necessary in order to understand its potential ecological impact and to develop effective treatment strategies (Haddis & Devi, 2007; Singare & Dhabarde, 2013).

Furthermore, the presence of heavy metals and other contaminants needs to be assessed so that the overall toxicity and potential health risks associated with the effluent discharge can be determined (Andreeva, 2021; Owalude et al., 2021; Ahmed et. al., 2022).

The enormous volume of wastewater generated by food processing industries are often discharged without adequate treatment thus significantly contributing to environmental degradation and public health risk (Omuku et. al., 2024; Kato & Kansha, 2024). A thorough characterization of food industry effluents is necessary in order to develop a sustainable water management practice and mitigate effluent ecological footprint (Asgharnejad et. al.,2021).

The negligence or limited attention to waste management and control by the food industry has left much to be desired in the proper discharge of the effluent generated (Nkwocha et. al., 2013).

The food processing industry located in a Port Harcourt suburb is involved in vegetable oil and pasta noodle production. The food industry generates wastes which are majorly in solid and liquid forms. The solid wastes are generated from the flour mixing unit obtained as spills (crumbs and over burnt noodles) from the noodle frying section, wrapping papers from the packaging unit and off specs (over and under fried noodles) from the frying unit. However, the off specs are used as animal feed while the dry solid wastes like flour spills and waste packaging materials are disposed of with the other domestic waste into municipal garbage systems (Bhatia, 2005).

Sources of waste water or effluent within the facility include cleaning of vegetable oil tanks, greasy floor washings and cleaning of dough mixers. Also, machine repair floors also contribute to the effluents after washings. (Noukeu & Ekodeck, 2016). OSI (2019) reported that one of the major problem food processing industries encounter is the presence of spent oil in their wastewater stream. This oil in water usually come from the leftover or spent oils used in processing the foods. The used oil is usually drained and re-used but some are washed and flushed out during housekeeping and maintenance. This liquid effluent when discharged from the industry without adequate treatment becomes a problem in the environment (OSI, 2019).

Government policies on environmental issues must be clearly stated if measures designed to protect the environment will be effective. This is very important because no amount of technological (or scientific device) or design can effectively protect the environment without the legal system to sustain them (Okorodudu & Fubara, 1988). The attention of the Nigeria government was first drawn to environmental issue after the incident of toxic waste dump at Koko, Delta in 1987. Following the incident, the Federal environmental protection agency (FEPA) was created. Its mandate was to formulate policies and coordinate activities that manage environmental issues. In 1999, FEPA was restructured to become the Federal ministry of Environment (FMENV). FMENV lacked powers to enforce these laws. This led to the creation of the National environmental standards and regulation enforcement agency (NESREA) in 2007. The agency is saddled with the responsibility of monitoring industries and enforcing environmental laws in the country (Ogbodo & Gozie, 2009). The key environmental challenges associated with the food processing industries are the management of waste water and solid wastes generated in the various stages. The absence of an efficient effluent monitoring system especially in most food processing industry especially in the developing countries has have left much to be desired with respect to pollution mitigation and control (Nkwocha et al, 2013)

Alamm et al (2007) reported that waste water from food industries studied showed high iron concentrations as well as high BODs. Bhatia (2005) observed that, though the food industries are not as polluting as some sectors such as metal, leather, oil and gas industries, they also contribute to air, water and soil pollution through the emission of particulate matter and unpleasant odour, discharge of liquid effluent with high organic content and large quantities of sludge. However, waste water is the primary area of concern in the food processing industry. If the effluents are contaminated with toxic metals, it will adversely affect human health as well as flora and fauna.

Environmental problems have increased in geometric proportion over the last three decades, with improper and inadequate management practices being largely responsible for the gross pollution of the aquatic environment (Osibanjo and Adie, 2007). Amabye (2013) noted that environmental pollution is caused to a large extent by aqueous discharges produced during industrial manufacturing processes which includes the food industry. In developing countries like Nigeria, pollution has continued to generate unpleasant consequences in health and economic development. The waste generated from food production can lead to surface and ground water contamination and as well stress the terrestrial wet land ecosystem if not adequately managed because of the presence of heavy metals, oil and grease in water and sludge discharged to land.

Most of the organic substances from industrial sources found in water can cause death or reproductive defects in aquatic fauna. The harmful substances discharged into aquatic habitat accumulate in animal tissues, sediment and find their way into drinking water supplies thus becoming a long-term health risk to humans (Alamm *et al*, 2007).

Although industries are expected to treat their effluents prior to discharge, most industries fail to meet the required standard for disposal due to lack of adequate treatment technology, infrastructure and selfish drive to make profit at the expense of best practices. This has resulted in the buildup of deleterious materials/ substances in the environment upon discharge. Proper treatment and monitoring of effluent are key to human and environmental survival (Bhatia, 2005).

The food industry operators take advantage of the fact that the pollution from their industry is often overlooked because of the focus on pollution from the oil and gas industry. This has made some of the operators of the food industry to carry out their operations and discharge effluents without treatment. This study thus assessed the quality of discharged effluent from a typical food industry on a recipient environment and it is hoped that this will spur further studies related to this study. In a bid to comply with statutory requirement for pollution control in Nigeria, the industry under study discharge its effluent on land rather than on surface water. Verbal inquiries revealed that this food industry initially channeled their effluent directly into the nearby river but had to stop due to community agitations against the practice which made the management resort to discharge on land.

MATERIALS AND METHODS

Sample Collection

The effluent from a noodle pasta production factory in Port Harcourt, South-south, Nigeria was collected outside the factory. The effluent / waste water was monitored for three months between April and June (twice a month). Effluents were discharged into a dug-out channel leading to neighboring marshland. Samples were collected from three points along the channel. The grab sample method was used for collection of the sample. Clean wide necked 1 litre sample bottles were used. These were properly labeled indicating sample name and date of collection. The field sampling and data acquisition were carried out using the following among others; glass sampling bottles, plastic sampling bottles, Hanna pH meter, conductivity, and turbidity field test meters.

The effluent waste water was sampled twice monthly for three months (April to June, 2022) while the sediment from recipient soil was sampled once each month. Effluent samples were obtained from three points along an approximately 220 metres stretch of a 2m wide by 1.5m deep dug- out trench channel created for effluent discharged. The sampling point were designated as follows; SPT (source point), which is nearest to where effluent leaves the factory; MPT (midpoint), the point approximately equidistant between the marsh land and effluent source while the EPT (end point) is the marshland area where the effluent largely accumulates and spreads. The control sample was collected from an open field area within a university campus 3 kilometres away from the sampling location. The soil and accumulated rainfall water were sampled as control. In sample handling and collection, wide necked sample bottles were used to collect samples. The sample bottles were thoroughly washed using mild detergent and water. Glassware brush was used to remove oil, dirt or dust that might have adhered to the walls of the container. Samples for oil and grease test were collected using glass bottles. The sample bottles were filled to the mouth to ensure no air space was left in order to prevent oxidation reaction.

Testing Methods

Standard methods recommended by APHA and ASTM were used to determine COD, BOD_5, SO_4^{2-}, Cl^-,PO_4^{3-}, NO_3^{2-} (ASTM, 1995). pH was determined using the HANNA digital pH meter. Metals were determined using Atomic Absorption spectrophotometer (AAnalyst 200). SO_4^{2-},PO_4^{3-} and NO_3^{2-} were determined using the thermo spectronic genesys 20 spectrometer.

Determination of chlorides content:

Standard solution of NaCl was prepared by dissolving 8.24g of oven dried NaCl in distilled water and made up to 500cm^3. 50cm^3 of the resulting solution was diluted to 1000cm^3. Each 1cm^3 of the new solution contained 0.500mg Cl^-. Standard $AgNO_3$ solution was also prepared by dissolving 2.396g $AgNO_3$ in 1 litre of distilled water. The resulting solution is equivalent to 0.500mg Cl^-. This was standardized against standard NaCl solution. The potassium chromate indicator used was prepared by dissolving 8g of K_2CrO_4 in 100cm^3 distilled water. 10cm^3 of the sample was transferred into a beaker. Few drops of K_2CrO_4 indicator added. This was titrated against $AgNO_3$ solution. The appearance of a red brick color indicated the end point.

$$\text{Chloride content (mg/l)} = \frac{volume\ of\ \text{AgNO3 titrated}\ X\ 1000\ X\ 0.5}{volume\ of\ sample} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Determination of chemical oxygen demand (COD) by dichromate method:

Chemical oxygen demand (COD) of each of the effluent samples was determined using the dichromate. 10cm^3 of the sample was poured into an Erlenmeyer flask. 1cm^3 20% H_2SO_4 and 1cm^3 $KMnO_4$ was added to the sample including blank. These were incubated at 27^{0}C for 4 hours. The change in colour was monitored and noted and at such instance, 1cm^3 more of reagent was added taking note of such addition. After four hours, 10% KI was added to the sample and this was titrated with 0.0125N Na_2SiO_3 using starch indicator. The results for blank and sample readings were recorded. 0.0125N KMnO4 was prepared by first diluting 125cm^3 of 0.1N $KMnO_4$ solution, with distilled water to make up to 1000cm^3 of 0.0125N Na_2SiO_3 solution, and making up to 1000cm^3 distilled water. 20% v/v H2SO4 was prepared by dissolving 20cm^3 H_2SO_4 Analar in 100cm^3 distilled water. 1% starch solution was prepared by dissolving 1g of solid starch in 100cm^3. 10% KI was prepared by dissolving 10% KI in distilled water. Hence, in calculation;

For 1cm^3,

$$\text{COD(mg/l)}= \frac{(Blank\ titre - Sample\ titre) X\ 1000}{Volume} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Determination of Biochemical Oxygen Demand (BOD):

The BODs of samples were determined by winkler method. Manganese sulphate solution was prepared by dissolving 40.0g $MnSO_4.H_2O$ in 25cm^3 of distilled water in a beaker. This was transferred to a 100cm^3 volumetric flask and made up to mark. Alkaline potassium iodide reagent was prepared by dissolving 70g KOH and 15g KI in 75cm^3 distilled water. The solution was cooled and made up to 100cm^3. Starch solution was prepared by adding a pinch of soluble starch to about 20cm^3 water; the solution was boiled and cooled. 0.025N sodium thiosulphate, $Na_2S_2O_3.5H_20$ solution was prepared by diluting 12.5cm^3 of stock solution and diluting to

500cm^3 with distilled water. 0.613g K_2CrO_7 (dried at 25^{0}C) was dissolved in 500cm^3 distilled water. Standardization of K_2CrO_7 was done by titrating against 0.025N $Na_2S_2O_3.5H_20$. Using a pipette, 10cm^3 sample was transferred into the amber bottle and made up with distilled water. A clear bottle was also filled with distilled water only. The contents of both bottles were then transferred into a conical flask. From the resulting mixture in the flask, both bottles were refilled again. Using a pipette, 0.5N $MnSO_4$ solution of 0.5N KOH and 0.5N KI solution were added into the clear bottles and amber bottles. Concentrated H_2SO_4 was added and 2.5cm^3 portion was taken. Starch indicator was added and this was titrated against 0.025N $Na_2S_2O_3.5H_20$. A Blue Black colour change indicated the end point. The result obtained represented the initial dissolved oxygen value; D.O$_1$. The amber bottle sample was kept in a dark place and incubated at room temperature for five days after which titration was repeated as above to determine D.O$_2$. Hence,

BOD (mg/l) $=\frac{(\mathrm{D.O1-D.O2})}{P}$ ……………………………………………(3)

Where D.O$_1$ = D.O value of diluted sample 15 minutes after dilution. D.O$_2$ = D.O value of diluted sample after five days incubation.

P = Fraction of sample expressed as $\left(\frac{ml\ of\ sample}{ml\ of\ distilled\ water}\right)$ …………..(4)

Determination of sulphate concentration:

Standard solution was prepared by pipetting 25cm^3 of the sulphate stock solution and transferring into a 500cm^3 volumetric flask. Sulphate stock solution was prepared by weighing 453.4mg K_2SO_4 and drying at 105^{0}C. serial dilution volume was determined using the dilution equation,

$C_1V_1=C_2V_2$ …………………………………………(5)

10cm^3 of sample was transferred into a test tube and a pinch amount of $BaCl_2$ was added. This was allowed to stand for some time until turbid appearance was observed. Blank was determined using distilled water in a cuvette. 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0cm^3 of the standard solution were respectively transferred into 50cm^3 volumetric flasks and were made up to mark. The absorbances of the concentrations were determined and a graph of concentration against absorbance was plotted. The value obtained as the slope was used to determine corresponding slopes of concentration. Thus, sulphate concentration (mg/l)= 114.578 x absorbance value obtained.

Determination of phosphate concentration:

The phosphate concentration in water sample was determined using a mixed reagent comprising of ammonium molybdate , ascorbic, potassium antimony tartrate and hydrogen tetraoxosulphate VI acid. Ammonium molybdate, $(NH_4)_6Mo.4H_20$ solution was prepared by dissolving 4g in 100cm^3 distilled water. Ascorbic acid was prepared by dissolving 1.76g in 100cm^3 potassium antimony tartrate, $K(SbO)C_4H_4.\frac{1}{2}H_2O$ solution was prepared by dissolving 0.28g in 100cm^3 distilled water. 5N H_2SO_4 was prepared by measuring 140cm^3 conc. H_2SO_4 and made up to 1 litre in a volumetric flask. A combined reagent was prepared by mixing 5cm^3 of 5N H_2SO_4, 0.5cm^3 of potassium antimony tartrate, 1.5cm^3 of ammonium molybdate solution, and 3cm^3 of ascorbic acid in the order listed. 0.8cm^3 of the combined reagent was added to 5cm^3 of sample in a test tube. This was observed for thirty minutes, for colour change; which indicate presence of phosphates. Phosphates concentration was determined using the filter photo colorimeter. Absorbance was measured at 880nm using the combined reagent with distilled water as blank or reference solution. 5cm^3 of distilled water was used for the reference instead of 5cm^3 of the sample. The absorbance of the sample was then determined (APHA, 1985).

Calculation,

$\sum P$ = Absorbance X 10……………………………… ….(6)

Standard phosphate solution was prepared by dissolving 219.5mg KH_2PO_4 and diluted to 1000cm^3,

$1.00cm^3 = 50.0\mu g\ PO_4 = 0.05mg\ PO_4$……………………….(7)

Then using the dilution equation,

$C_1V_1 = C_2V_2$

Where C_1= concentration of standard phosphate solution= 0.05mg/l

V_1= volume of standard phosphate solution required= ?

C_2= Concentration of diluted phosphate solution=0.0001mg/l

$V_2 = (0.0001 \times 50)/0.05 = 0.1cm^3$,

To obtain a 0.001mg/l phosphate solution, $0.1cm^3$ of the standard solution was diluted to $50cm^3$ in a volumetric flask. Series of concentration were obtained following the same procedure above. Thus, 0.002, 0.003, 0.004, 0.005, 0.006mg/l PO_4 solution were prepared. Their corresponding absorbance was determined using the filter photometer at 470nm. The curve was obtained by plotting concentration against absorbance. The slope obtained gave the multiplying factor used to determine PO_4 concentration of sample from absorbance (APHA, 1985).

Determination of nitrate concentration:

25% brucine reagent was prepared by dissolving 2.5g of brucine sulphate in $100cm^3$ glacial acetic acid. The reagent was stored in the dark. Care was taken in handling the reagent due to its toxicity. 50mg/l of standard NO_3 solution was prepared by dissolving 1.1805g of KNO_3 in $500cm^3$ of the extracting solution. $0.5cm^3$ chloroform was added as a a preservative. From the stock solution, various nitrate standard: 0.001, 0.003, 0.005, 0.007, and 0.010 were prepared. $0.5cm^3$ of the brucine reagent and $0.2cm^3$ conc. H_2SO_4 was added to $10cm^3$ of the sample in a beaker. The mixture was then heated on a heating block until a colour change was observed. This was then air-cooled for 15min. and absorbance was measured using the genesis 20 spectrometer.

Calculation,

$\sum N = \text{Absorbance} \times 1.6$ ………………………………………………………….(8)

Determination of heavy metal concentration:

Heavy metal concentrations of effluents and sediments were determined only after sample digestion have been carried out. For effluent sample, $50cm^3$ sample was vaporized. $5cm^3$ perchloric acid and $5cm^3$ nitric acid was added.. these were now transferred into sample bottles in preparation for analyses. The atomic absorption spectrophotometer (AAS), perkin elmer AAnalyst 200 was used to analyse the samples. For sediment samples, the samples were air-dried and then heated in an oven at 100^0C. This was then ground and then sieved with a 1 millipore sieve to remove coarse particles. 2.0g of the fine sample was weighed. Perchloric acid and concentrated HNO_3 in ratio 1:3 was added. In a $100cm^3$ beaker, the mixture was heated for 15 minutes until gases evolved. $50cm^3$ of distilled water was then added. This was finally transferred into sample bottle for storage preparation for analysis. Analysis was carried out using Perkin Elmer Aanalyst 200 AAS

Determination of turbidity:

$50cm^3$ of effluent sample was transferred into the turbidimeter tube. This was shaken to disperse any solid and left to stand until all air bubbles have dispersed. The sample was decanted into the cuvettte of the turbidimeter and the cuvette was transferred into the hack 310 turbidimeter. Turbidity was read directly from the scale and recorded in nephelometric turbidity unit (NTU). (ASTM,1995).

RESULTS

The data on tables 1 and 2 below are the results obtained for the food effluent and the recipient soil. These are presented as follows;

Table 1: Physicochemical characteristics of food industry effluent and regulatory limits

PARAMETER	SPT MEAN	MPT MEAN	EPT MEAN	OVERALL MEAN	CONTROL	WHO/ NESREA
pH	5.05±0.75	4.95±0.76	5.27±0.49	5.09±0.60	6.05±0.25	6.0-9.0
EC, µs/cm	69.5±18.3	71.0±31.3	80.0±26	73.5±22.9	17.5±5.2	≤1000
Oil & grease	431.2±11.5	516±24.3	1154±77.0	700.5±53.2	1.58±0.4	10-20
BOD,mg/l	26.8±4.5	32.5±4.47	43.9±10.3	34.42±4.4	2.8±0.54	≤30
COD, mg/l	159±5.1	151.8±5.8	149.5±6.8	153.4±9.7	11.0±2.6	≤150
Sulphates,mg/l	101.2±5.8	81.3±4.7	93.2±6.5	91.9±5.5	8.26±1.97	≤500
Chlorides,mg/l	84.2±4.7	103.5±7.4	103.5±7.1	97.06±5.7	8.0±2.3	≤600
Turbidity,NTU	44.9±12.1	36.5±6.5	39.5±6.60	40.3±8.5	21.0±4.3	≤5-10
TOC, mg/l	34±8	57±6	63±3	51.3±5.7	16.5±1.8	≤30
Fe, mg/l	0.67±0.21	0.89±0.18	1.17±0.08	0.77±0.25	0.19±0.03	≤1.0
Zn. mg/l	0.077±0.04	0.087±0.013	0.153±0.014	0.08±0.04	0.05±0.01	≤1.0
Pb, mg/l	0.05±0.002	0.053±0.0067	0.053±0.006	0.05±0.002	0.001±0.0	≤0.1
Cu, mg/l	0.067±0.007	0.077±0.0081	0.06±0.002	0.072±0.008	0.06±0.01	≤1.0
Cr, mg/l	0.06±0.00	0.06±0.00	0.06±0.00	0.06±0.00	0.01±0.001	≤0.1
Cd, mg/l	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00	0.001±0.0	≤0.01
Ni, mg/l	0.063±0.01	0.087±0.011	0.067±0.003	0.075±0.013	0.03±0.01	≤0.2

The data on Table 1 above represent results from tests carried out on effluent samples collected from each designated sampling points (i.e SPT, MPT, EPT) along the dug-out channel. The average at each point is presented and the overall mean was determined from the values obtained at the three points for each parameter.

The pH values of the effluent at SPT, MPT, EPT were 5.05, 4.95, 5.27 respectively giving a mean of 5.09±0.60. Electrical conductivity (EC), values at SPT, MPT, EPT were 69.5, 71.0, 80.0µs/cm respectively with a mean of 73.5±22.9µs/cm. Oil & grease values SPT, MPT, EPT were 431.2, 516, 1154mg/l with a mean of 700.5±53.2. BOD values at SPT, MPT, EPT were 26.8, 32.5, 43.9mg/l giving a mean of 34.42±9.7mg/l. COD values at SPT, MPT, EPT were respectively 159, 151.8, 149.5mg/l with a mean of 153.4±4.4mg/l. sulphates concentration values at SPT, MPT, EPT were 101.2, 81.3, 93.2mg/l respectively giving a mean of 91.9±5.5mg/l. Chlorides concentration values at SPT, MPT, EPT were respectively 84.2, 103.5, 103.5mg/l and had a mean of 97.06±5.7mg/l. Turbidity values at SPT, MPT, EPT were 44.9, 36.5, 39.5NTU respectively with a mean of 40.3±8.5NTU. TOC values at SPT, MPT, EPT were 34, 57, 63mg/l with a mean of 16.5±1.8mg/l.

Fe values at SPT, MPT, EPT were 0.67, 0.89, 1.17mg/l with a mean of 0.77±0.25mg/l. Zn values at SPT, MPT, EPT were 0.077, 0.087, 0.153mg/l with a mean of 0.08±0.04mg/l. Pb values at SPT, MPT, EPT were 0.05, 0.053, 0.053mg/l with a mean 0.05±0.002mg/l. Cu values at SPT, MPT, EPT were0.067, 0.077, 0.06mg/l respectively with a mean of 0.072±0.008mg/l. Cr values at SPT, MPT, EPT all recorded 0.06mg/l giving the mean as the same value. Cd values at SPT, MPT, EPT were 0.01mg/l at all point giving a mean of the same value. Ni values at SPT, MPT, EPT 0.063, 0.087, 0.067mg/l giving a mean of 0.075±0.013mg/l.

Table 2: Physicochemical Characteristics of the recipient soil over a Three- month period

PARAMETER	SPT MEAN	MPT MEAN	EPT MEAN	OVERALL MEAN	CONTROL	WHO/ NESREA
Ph	5.98±0.21	6.44±0.14	6.17±0.09	6.20±0.15	6.63±0.09	6.0-8.5
EC, µS/cm	88.5±17.67	173.5±0.71	140.5±9.19	134.2±8.8	9.0±0.6	1<4000
Oil& Gr, mg/kg	3854±122	3180±136	2288±143	3107±137	126±14	1<50
Sulphates, mg/l	60.55±2.94	124.6±6.6	68.9±2.8	84.67±4.11	8.26±0.64	<500
Chlorides, mg/kg	410±41.4	526±54	538.5±44	491.5±49	20±1.6	<250
∑P, mg/kg	31.4±0.87	31.6±2.7	33.6±2.0	32.2±0.63	16.3±0.13	<100
∑N, mg/kg	14.4±1.5	10.6±0.7	10.8±0.9	11.9±1.3	7.0±0.1	<50
TOC,%	2.5±0.21	2.3±0.4	3.5±0.4	2.77±0.34	1.24±0.4	NA
Fe, mg/kg	13.11±2.46	36.03±0.42	20.5±1.27	23.2±0.76	13.16±0.36	<50
Zn, mg/kg	4.49±0.19	4.12±0.21	3.65±0.21	4.09±0.20	1.02±0.01	<140
Pb, mg/kg	1.3±0.00	1.63±0.177	1.76±0.176	1.56±0.21	0.33±0.011	<50
Cu, mg/kg	11.8±1.4	19.9±0.5	14.6±1.8	15.4±1.7	4.4±0.12	<100
Cr, mg/kg	0.56±0.0	0.6±0.00	0.65±0.0	0.6±0.0	0.03±0.0	<10
Cd, mg/kg	0.1±0.0	0.21±0.28	0.11±0.013	0.14±0.03	0.02±0.0	<1.0
Ni, mg/kg	1.15±0.11	3.85±0.78	4.45±0.16	3.15±0.056	0.01±0.00	<50

The pH values of the recipient soil at SPT, MPT, EPT were 5.98, 6.44, 6.17 respectively giving a mean of 6.20±0.15. Electrical conductivity (EC), values at SPT, MPT, EPT were 88.5, 173.5, 140µs/cm respectively with a mean of 134.2±8.8µs/cm. Oil & grease values SPT, MPT, EPT were 3854, 3180, 2288mg/kg with a mean of 3107±137mg/kg. Sulphates concentration values at SPT, MPT, EPT were 60.55, 124.6, 68.9mg/kg respectively giving a mean of 84.67±14.6mg/kg. Chloride concentration values at SPT, MPT, EPT were respectively 410, 526, 538.5mg/kg and had a mean of 491.5±49mg/kg. Total Phosphates (∑N) values at SPT, MPT, EPT were 31.4, 31.6, 33.6mg/kg respectively with a mean of 32.2±0.63mg/kg. Total nitrates (∑N) at SPT, MPT, EPT were 14.4, 10.6, 10.8mg/kg with a mean value of 11.9±1.3mg/kg. TOC values at SPT, MPT, EPT were 10.5, 10.3, 13.5% with a mean 11.2±3.4%.

Fe values at SPT, MPT, EPT were 13.11, 36.03, 20.5mg/kg with a mean of 23.2±0.76mg/kg. Zn values at SPT, MPT, EPT were 4.49, 4.12, 3.65mg/kg with a mean of 4.09±0.20mg/kg. Pb values at SPT, MPT, EPT were 1.3, 1.63, 1.76mg/kg with a mean 1.56±0.21mg/kg. Cu values at SPT, MPT, EPT were 1.18, 1.99, 1.46mg/l respectively with a mean of 1.54±0.17mg/kg. Cr values at SPT, MPT, EPT all recorded 0.56, 0.6, 0.65mg/kg giving the mean value of 0.60mg/kg. Cd values at SPT, MPT, EPT were 0.10, 0.21, 0.11 mg/kg with a mean value 0.14±0.03mg/kg. Ni values at SPT, MPT, EPT 1.15, 3.85, 4.45mg/kg giving a mean of 3.15±0.056mg/kg.

DISCUSSION

The tables of results are analyzed in two sections; the effluent and the recipient soil. These are discussed as follows;

Effluent

pH

From the data in Table 1, the pH of the food processing industry effluent ranged from 4.95 to 5.27and is below the WHO/NESREA permissible limits which is indicative of acidity. The ascidity of the effluent may be due to the use of acid, production of acidic byproduct. Also, it could be due to industrial emissions. The chemical changes in water influences its pH. It is significant that none of the effluent pH fell within the regulatory limit of 6-9. However, the control pH (6.05) is within the permissible limit. Qasim and Mane (2013) reported pH of 7.10, 5.64 and 6.25 for the effluents from dairy, sweet-snack and ice-cream processing industries respectively. Siyanbola et al (2011) investigated the effluent from five different food industries and reported pH of 3.03, 1.36, 1.61, 1.71 and 4.91. The pH of the effluent under study was more acidic than pH values reported by Qasim and Mane (2013) but less acidic than that reported by Siyanbola et al (2011). Nwosu et al (2014) reported a pH range of 2.91-5.62 for three food processing industries. These pH results obtained showed that the effluents were not properly treated and also indicated a possible poor in house treatment of effluents by the industry. The mean pH of the effluent (5.09±0.60) is below the range of 6.0-9.0. This is indicating potential environmental concerns. This may suggest that the neutralization process was not carried out or poorly carried out on the effluent. Emodi (2020) analyzed effluents from an industrial area in Enugu and obtained pH as 8.6. This is higher than the pH of the effluent under study and within the limit. Also, Abrha & Chen (2017) analyzed effluents from different Beverage Industry in Ethiopia and recorded pH in the range 5.21-12.37. The effluents from the beverage industry were either acidic or alkaline depending on the composition of each food industry effluent. The food industry effluent was on the acidic range. This acidic pH values observed may potentially impact biological treatment efficiency thus necessitating neutralization steps prior to further treatment processes.

Electrical Conductivity

Electrical conductivity measures the ease with which a solution allows electric charge or heat to pass through it. The presence of ionizable solutes in effluent contributes to its conductivity (Bhatia, 2005). The conductivity of control sample (17.5±5.2, µS/cm) was lower than the mean conductivity value of the effluent samples (73.5±22.9µS/cm) indicating the presence of ionizable salts in the discharged wastewater. High electrical conductivity value is an indication of contamination and may lead to corrosion of equipment and pipes. This might be from the dissolved salts washed off with the effluents. The highest value obtained for conductivity was 80±26us/cm at EPT while the lowest value of 69.5±18.3µs/cm was recorded at SPT. The conductivity values were however generally below the permissible limit of 1000µs/cm.

Oil & Grease

The Oil & Grease values were significantly high, having a mean of 700.5± mg/l, which far exceeds the ≤10 mg/l regulatory limit. The value suggests a considerable organic load presence. This is likely due to grease trap and oil skimmer overload due to high oil and grease content in raw effluent. There was an insignificant presence of oil and grease in the control having a value of 1.58±mg/l. The elevated levels of oil and grease, as depicted in the effluent result, not only contribute to the high organic load of the effluent but also present specific challenges in wastewater treatment due to their immiscibility and tendency to foul treatment equipment. This necessitates a comprehensive treatment approach that includes effective pre-treatment stages to remove these components. Oil-water skimmers, separator or centrifuge should be effectively used to remove floating oil mass. Also, coagulants should be added to the effluent to break emulsions and facilitate removal of oil. Biological treatment using microorganism could be employed to biodegrade oil and grease. Finally, advanced tertiary treatments such as membrane filtration could also be employed to ensure compliance with stringent environmental regulations.

BOD & COD

Biochemical oxygen demand (BOD) measures the amount of dissolved oxygen required by aerobic organisms for the decomposition of organic matter present in a given aquatic medium (Bartram, 2005). It defines the extent of pollution of the water while chemical oxygen demand (COD) measures all chemically oxidizable matter present in water. The mean BOD value was 34.42±4.7 mg/l which is slightly above the ≤30 mg/l regulatory limit. This indicated that there is a high demand for oxygen by microorganisms to break down organic matter in the effluent. The control recorded BOD value of 18±3.4mg/l. The COD recorded mean value of 153±9.7mg/l and the control COD value was 54.6±4.6mg/l. Effluent samples from two top Nigerian food industries (biscuit and beverage production) were investigated, the biscuit industry recorded higher BOD and COD values than the beverage industry effluent (Osho et. al, 2010). Noukeu et. al. (2016) characterized the effluent from food processing industries and observed that biscuit factory recorded a BOD value of 1126±27.6mg/l. This value was far higher than the effluent of the food industry under study. There is the need to evaluate the adsorption capacity of various treatment methods for these pollutants, as demonstrated in studies where significant reductions in BOD and COD were achieved (Kholif et al, 2023). This highlights the effectiveness of such approaches in enhancing water quality. Specifically, orthophosphoric acid-modified rice husk activated carbon has shown substantial efficacy in treating fast-food wastewater, leading to significant reductions in BOD and COD, thereby minimizing environmental impact (Omuku et al., 2024). The high levels of organic matter, particularly reflected in the COD and BOD values, suggest a possible pollution potential thus this necessitates using robust wastewater treatment strategies before discharge. The BOD can be improved through anaerobic digestion which would aid the breakdown of organic matter. To improve COD, membrane filtration or absorption can be used including processes like flocculation and coagulation.

Turbidity

The turbidity of water describes the extent of non-clarity of the water due the presence of particles not readily visible to the naked eye. It attests to the quality of water. Turbidity value for the effluent ranged from 36.5-44.9 NTU. The turbidity value ranged from 36.5 to 44.9NTU with a mean value of 40.3±8.5NTU. The effluent turbidity value which is above the ≤5-10 NTU standard limit suggest a high concentration of suspended solids. This can affect penetration of light thereby negatively affecting aquatic plants. The effluent can be treated by physical processes such as filtration, centrifugation and sedimentation. Chemical treatment process such as flocculation and coagulation can also be applied to reduce turbidity by removing suspended solids. Also, activated sludge and trickling filters can be used to biologically treat the wastewater. Natural coagulants obtained from biomass have shown effectiveness in the reduction of turbidity in wastewater.

Total Organic Carbon (TOC)

Total organic carbon (TOC) is the measure of the organic molecules or contaminants present in a given sample of water. TOC value helps to assess if the water is fit for use in a desired process. All water contain carbon to differing extent. The permissible level for TOC is 30mg/l. The mean value (51.3±5.7mg/l) is above the ≤30 mg/l standard and is above the control value of 6.05±1.8mg/l. This indicates a moderate level of organic matter. When TOC level is high, it can lead to oxygen level depletion in water bodies. Thus, there is need to further treat the effluent to reduce TOC level to comply with regulatory standards. The organic compounds can be removed through activated carbon adsorption. Also, advanced oxidation such as the use of Fenton’s reagent, Ultra violet and ozone can help oxidize organic compounds. Biological treatment can be applied in which the organic matter would be biodegraded using aerobic or anaerobic processes.

Sulphates

Sulphates are the salts of sulphuric acid. They are inorganic ions that are found in nature and can be synthesized for industry. Sulphates are surfactants that enables surface tension of water to break up, hence, their use as active ingredients in the production of cleaning agents.

Sulphate concentration in the effluent were generally below the limit with the sixth week effluent recording highest value of 101.2±5.8mg/l at SPT and 81.3±4.7mg/l being the lowest value obtained at MPT. The mean TOC value was 91.9±5.5mg/l. This value is below the regulatory limit of ≤500mg/l. The control recorded 8.26±1.97mg/l which is far less than the value of the mean sulphate concentration of the effluent. This suggests that the effluent would be less harmful in th environment due to low sulphate concentration.

Chlorides

Chlorides are salts resulting from the reaction of chlorine gas and a metal. Some common chlorides are sodium chloride and magnesium chlorides. Chlorides are harmless at low concentration but at high concentration they are harmful to plants if used for irrigation or any agricultural purpose. Chloride concentration measured were all below acceptable limits of ≤600mg/l. The highest value for chloride concentration were recorded at MPT and SPT with values of 103.5±7.4mg/l and 103.5±7.1mg/l respectively. High chlorides content in effluent affects aquatic life and water quality. It can also be a major source of corrosion and equipment damage.

Heavy Metals

Heavy metals are naturally occurring elements with densities above 5g/cm^3. They possess high atomic weight and are toxic to plant, animals and humans even at low concentration. They are non-biodegradable and are thus persistent in the environment. They are known to bioaccumulate in living systems causing irreparable damage.

The mean values of Iron, Zinc, Lead, Copper, Chromium, Cadmium, and Nickel were 0.77±0.25, 0.08±0.04, 0.05±0.02, 0.072±0.008, 0.06±0.00, 0.01±0.00, 0.075±0.013mg/l and they are within their respective permissible limits. However, their values are higher than the control values. High concentration of toxic metals result to accumulation in organisms, causing stunted growth, reproductive damage and even death. Discharge of untreated effluent with high heavy metal concentration into surface waters contaminate the water and exposure to this lead to bioaccumulation in aquatic organisms and may end up being consumed by humans leading to organ failure, cancer or neurological disorder. The environmental concerns of some specific toxic metals are as follows; chromium and nickel are carcinogenic and toxic while lead and cadmium are carcinogenic, nephrotoxic and neurotoxic. The effluent showed minimal presence of the toxic metals indicating a possible effectiveness in treatment

Recipient Soil

The data in Table 2, showing the physicochemical characteristics of the recipient soil, also indicates significant impact from the effluent:

pH

pH responds to any change in chemically composition of the aqueous solution. The mean pH of the soil (6.20±0.15) is within the acceptable range of 6.0-8.5. the control pH was 6.63±0.09. It is interesting to note that the pH of the recipient soil improved and was within the standard limit. This could be due to the buffering capacity of the soil which enables it to resist changes in pH. Soil minerals can react with acidic compounds giving rise to improved pH. Microbial activity can result to break down of organic matter which can buffer pH changes.

Conductivity

Conductivity is the measure of the ability of a medium to conduct electricity and it is related to the presence of ions in solution. Conductivity of soil recorded highest value of 140.5±9.19 EPT while the lowest value for soil conductivity was 88.5±7.67µs/cm. The conductivity values were higher than effluent values. The NESREA permissible limit for conductivity in sediment is 4000 µs/cm. Conductivity in sediment is definitely due to many factors making it not-assessable. However, setting limit ensures soil health and plant growth are not affected by excessive salinity.

Oil and Grease

Oil and grease include the fats, oils, waxes and other related constituents found mostly in wastewater. It can also be termed as any substance present in wastewater and recoverable by solubility in solvent. Oil and grease had its highest value of 3854±122mg/kg at SPT while the lowest value is 2288±143mg/kg. the overall mean oil and grease value was 3107±137mg/kg. The discharge of oily wastewater on land is a major source of land pollution. The aerobic condition of the soil is affected due to reduction in the oxygen content of the soil. This unusually high value for oil and grease suggested a discharge of wholly untreated effluent containing accumulated fats, grease and oil. However, none of the values obtained fell within the regulatory limit of 30mg/l. the control sample had a value of 126±14mg/kg. The non-compliance of the effluent samples confirmed that the effluent was not treated. The mean concentration of Oil & Grease in the recipient soil (3107± mg/kg) is exceedingly higher than the control (126± mg/kg) and the WHO/NESREA limit (<50 mg/kg). This indicates severe contamination of the soil with organic pollutants from the effluent and a result of accumulation over the period.

TOC

The mean TOC (2.77±0.34%) is notably higher than the control (1.24±0.4%). This is above the 1-2% limit range for agricultural soils. There is no set limit for TOC in soils. However, the value obtained points to organic matter accumulation. High TOC value range from 2-5%.

Sulphates

Much of the Sulphur containing fuels end up in soils as sulphates which react with soil water to form sulphuric acid. Most sulphates result from the oxidation of sulphuric acid (Bhatia, 2005). The range value of sulphate concentration in sediment was 60.55±2.94 to 124.6±6.6mg/kg which is however low when compared to permissible limit of less than 500mg/kg. Soils get enormous quantities of waste products each year which mainly include sewage effluent and unlimited varieties of industrial liquid wastes. The control sample for soil was significantly less (8.26mg/kg). It can also be observed that the sulphate values in soil were slightly lower in effluent. This could indicate the reason for the more acidic pH of effluent compared to the soil.

Chlorides

The mean chloride level (491.5± mg/kg) is significantly higher than the control (20 mg/kg) and exceeds the WHO/NESREA limit (<250 mg/kg). The Chlorides concentration measured were generally below the regulatory limits of 600mg/kg. The highest value for chloride concentration was 538.5±44mg/kg recorded at EPT while the lowest value was 410mg/kg recorded at SPT. The values for chlorides concentration obtained for sediment were far above values obtained for effluent samples.

Phosphates

The mean phosphorus content (32.2±0.63 mg/kg) is higher than the control (16.3± 0.13mg/kg), although, within the WHO/NESREA limit (<100 mg/kg). Phosphate in soil can improve fertility of soil but when in excess, it can affect plant growth. This is because high phosphate in soil affects its pH and nutrient availability

Nitrates

The mean total Nitrogen (∑N) in the soil is 11.9±1.3mg/kg is higher than the control value of 7.0±0.1mg/kg. the nitrate concentration is adequate for agricultural soil as it fell within the 10-50mg/kg. Nitrate is ideal in moderate concentration but can be detrimental to plants in concentration.

Heavy Metal

The concentration of heavy metals in soil was compared with the NESREA standard limits. Iron at SPT, MPT and EPT were 13.11±2.46, 36.03±0.42, 20.5±1.27mg/kg respectively with a mean of 23.2±0.76mg/kg and the control value was 13.16±0.36mg/kg. Iron was below the regulatory limit of ≤100mg/kg. Iron deficiency can be detrimental to plants at low concentration and it can be toxic to plants at high concentration. The availability of iron also determines phosphorus and other nutrient availability.

The concentration of zinc metal in soil was compared with the NESREA standard limits. Zinc at SPT, MPT and EPT were 4.47±0.19, 4.12±0.21, 3.65±0.21mg/kg respectively with a mean of 4.09±0.20mg/kg and the control value was 1.02±0.01mg/kg. Zinc was below the regulatory limit of ≤100mg/kg. Zinc was within WHO/NESREA limits and showed higher values compared to the control, indicating some level of impact. It is however observed that the values for heavy metal concentration for effluent were far less than those of the soil. This may suggest a possible accumulation of heavy metals in the soil as a result of continual discharge of production process effluent on recipient land. This may however, not to be the only cause because other sources may be responsible for the accumulation.

The concentration of lead metal in soil was compared with the NESREA standard limits. Lead at SPT, MPT and EPT were 1.3±0.00, 1.63±0.18, 1.76±0.18mg/kg respectively with a mean of 1.56±0.0.50mg/kg and the control value was 0.33±0.18mg/kg.

The mean cadmium level (0.14±0.03mg/kg) is well above the control (0.02±0.00 mg/kg) and exceedingly below the WHO/NESREA limit (<3mg/kg), suggesting limited heavy metal accumulation in the soil. The mean nickel concentration (3.15±0.056 mg/kg) is significantly higher than the control (0.01± mg/kg), and still within the WHO/NESREA limit (<50 mg/kg). Lead, Copper, and Chromium levels were also at elevated compared to the control, but remain within WHO/NESREA limits.

CONCLUSION

The study investigated the food industry effluent and compared the result with that obtained from the recipient soil. The study revealed the presence of significant level of some contaminants in both the effluent and the recipient soil. The effluent itself consistently shows high levels of oil & grease, turbidity, and acidity (low pH) exceeding regulatory standards. The poorly treated effluent resulted to considerable pollution of the soil, particularly with very high concentrations of oil & grease. While some other parameters in the soil remain within standard limits, their elevated levels compared to the control indicate a clear impact from the industrial discharge. This data strongly supports the need for effective wastewater treatment before discharge to mitigate environmental degradation.

The results obtained from the study showed that the quality of effluent from the food industry was not satisfactory. Oil and grease particularly had an extremely high value which points to prove that the food industry did not treat their effluent before discharge. This fact can be confirmed by the values obtained for other parameters such as the pH, BOD, COD and turbidity values. The turbidity values were all above acceptable limits. COD values recorded several values above acceptable limits indicating the presence of chemically oxidizable matter in the wastewater. A comparison of the wastewater with the control sample further confirmed poor effluent quality as the control parameters fared better than the wastewater when both were compared with the regulatory values.

RECOMMENDATION

The disposal of quality effluent is very important if the recipient environment will be protected. It is therefore advised that the concentration of base required for neutralization in the treatment process be determined by carrying out a pilot study of the effluent to be treated. Also, an oil skimmer/ separator system such as described by OSI (2019) should be put in place to take care of oil and grease contents of the discharged effluent. The regulatory authority should generally ensure that industries embark on efficient treatment of their effluent and also routine monitoring of the effluent before and after discharge. It was also noted that effluent was poorly treated before discharged. Specialized waste management personnel should be involved to co-ordinate waste management plan of the factory. The use of effluent from food industry as an alternative substrate source for bio ethanaol production can be economically beneficial as it can reduce the need for treatment and discharge of the effluent (Ratanapongleka *et al*, 2010).

The environmental challenges identified in the effluent analysis of the food industry in Port Harcourt, a three-dimensional approach which should combine technological remediation, regulatory reform, and industry accountability is recommended.

With the high concentrations of oil, grease, BOD, COD, and turbidity observed in the effluent samples, appropriate remediation technologies should be adopted in the treatment of the effluent. Oil-Water Separators systems should be installed. This is essential for removing fats, oils, and grease from wastewater. The coalescing plate separators and dissolved air flotation units mostly used in food processing environments should be installed. These are capable of reducing oil concentrations to less than 0.1 ppm and thus improve downstream treatment efficiency. Early removal of oil in the treatment process improves water quality and reduces maintenance needs in food processing plants (OSI, 2022).

Organic pollutants should be biologically treated from the food effluent using Bioreactors such as Membrane Bioreactors. Sequencing Batch Reactors and aerobic reactors. These offer high-treatment efficiency. These systems are ideal for the treatment of food industry effluents that has varying composition and they can be scaled to meet different production volumes. Membrane Bioreactors are increasingly adopted in food factories due to their ability to handle fluctuating wastewater composition and meet stringent discharge standards (Sperta Systems, 2021). The system ensures high removal efficiency for BOD, COD, and nutrients and it is suitable for water reuse applications.

Constructed Wetlands could be engineered from wetlands to provide a sustainable, low-maintenance solution for nutrient and organic matter removal. The aerated subsurface flow wetlands are particularly effective in reducing BOD and suspended solids while enhancing ecological aesthetics (Salah-Tazdaït & Tazdaït, 2023; Odedra & Patel, 2022). Salah-Tazdaït & Tazdaït (2023) emphasized that aerated constructed wetlands can significantly reduce organic pollutants in food industry wastewater, offering a sustainable alternative to conventional treatment methods. These technologies should be adopted to meet specific effluent profile treatment. This can then be integrated into an elaborate Environmental Management System (EMS) to ensure consistent in performance and regulatory compliance.

The study showed that an effective compliance enforcement mechanism was lacking in Port Harcourt. There is therefore the need to strengthen regulatory enforcement to improve compliance. Regulatory agencies such as NESREA should be equipped with adequate resources for regular inspections and real-time monitoring. The Penalties for non-compliance should be revised to serve as effective deterrents. Industries should be mandated to publicly disclose effluent data to ensure transparency and community oversight. Also, it is necessary to reform policies and introduce industry incentives to close existing policy gaps: Adoption of sustainable practices by industries should attract incentives through tax breaks, green certifications, and public recognition for adopting sustainable practices.

Effluent discharge standards should be updated to reflect current scientific benchmarks and should also include emerging pollutants. A clear mechanism for accountability should be integrated into environmental policies to define roles and responsibilities. Public enlightenment, engagement and education should be initiated to encourage a culture of accountability and commitment to environmental matters. The Local communities should be empowered to participate in environmental monitoring and advocacy. This integrated approach would not only address the technical deficiencies observed in the Port Harcourt case study but would also lay the groundwork for scalable, sustainable solutions across Nigeria's food processing sector.

The findings from the effluent analysis of the noodle pasta and vegetable oil production industry in Port Harcourt reveal significant environmental degradation, characterized by elevated levels of oil, grease, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), turbidity, and acidity. These indicators point to inadequate wastewater treatment and poor adherence to environmental standards. However, the persistence of such pollution is not merely a technical failure. It reflects deeper systemic challenges in enforcement, policy, and industry accountability.

Enforcement Deficiencies

Environmental compliance enforcement is with a lack-lustre attitude despite the existence of regulatory agencies such as NESREA. Regular inspections with real-time monitoring is absent making the industries to discharge untreated effluents with minimal fear of sanctions. The absence of an oil-water separator in the studied facility, which should be the primary pollution mitigation device suggests that regulatory monitoring is either ineffective or absent. Finally, it is likely that due to the influence these industries have on the economy of the region, there is limited transparency and political interference in the enforcement of compliance.

Policy and Regulatory Gaps

Environmental policies in Nigeria often lack effective mechanisms for accountability and integration because outdated effluent standards fail to address emerging pollutants or reflect current ecological risks. The absence of seasonal sampling in the study also underscores the need for more comprehensive regulatory frameworks that mandate longitudinal data collection.

Implications for Policy and Practice

This study mirrors the challenges facing environmental monitoring and control in Nigeria's industrial sectors. These issues require a multi-dimensional approach such as updating regulatory standards, fostering community engagement, strengthening institutional capacity, and incentivizing industry compliance. With these reforms, the public health and ecological risks posed by untreated effluents will be effectively checked.

Finally, proper pollution management/ abatement practices should be implemented to ensure the preservation of other uses of water. Thus, an in-house treatment of effluents from industries should be the paramount part of the food production industry's operations and the regulatory authority must take an uncompromising stand in ensuring compliance. This is more so, if environmental sustainability is to be achieved.

REFERENCES

1. Abrha, B.H. & Chen Y. (2017). Analysis of Physico-Chemical Characteristics of Effluents from Beverage Industry in Ethiopia. journal of geoscience and environmental protection. 6(5), 3-6.IOP Publishing
2. Aderibigbe,D.O, Giwa A.RA., Bello A.I. (2018) Characterization and treatment of wastewater from food processing industry milk. Imam Journal of Applied Sciences. Wolters Kluwer publishers. 2(4), 27-36.
3. Alamm, A.S.M.M; Hossain, K..M, Hossain B.; Ahmed, A; Hoque, M.J (2007). A Study on waste effluents and their Management at selected food and beverage industries of Bangladesh, Journal of Applied science and Environmental Mgt. 11(4)5-9.
4. Al-Huqail, A. A., Kumar, P., Eid, E. M., Adelodun, B., Abou Fayssal, S., Singh, J. & Širić, I. (2022). Risk assessment of heavy metals contamination in soil and two rice (Oryza sativa L.) varieties irrigated with paper mill effluent. *Agriculture 12*(11), 1864.
5. Amabye, T.G (2015). Effect of Food Processing Effluents on the Environment: A Case Study of MOHA Mekelle Bottling Company, Tigray, Ethiopia. ISSN2469-9764 ICO. Open Access Journal.

6. Amin, A., Ahmad, T., Ehsanullah, M., Khatak, M.M., & Khan, M.A. (2010). Evaluation of industrial and city effluent quality using physicochemical and biological parameters. Electronic Journal of Environmental, Agriculture and food chemistry, 9 (5), 2010. [931-939]. ISSN: 1579-4377
7. APHA (1985). Standard methods for the examination of water and wastewater. American public health association. 15th edition.
8. Arti, & Mehra, R. (2023). Analysis of heavy metals and toxicity level in the tannery effluent and the environs. Environmental Monitoring and Assessment, 195(5), 554.
9. Asgharnejad, H., Khorshidi Nazloo, E., Madani Larijani, M., Hajinajaf, N., & Rashidi, H. (2021). Comprehensive review of water management and wastewater treatment in food processing industries in the framework of water-food-environment nexus. *Comprehensive Reviews in Food Science and Food Safety*, *20*(5), 4779-4815.
10. ASTM (1995). Water and Environmental technology. American standard testing methods. Vol. 1 & 11.
11. Bhatia, S.C (2005). Environmental Pollution and Control in Chemical Process Industries, Khanna Publishers, New Delhi. Pp. 47-79.
12. Biragova, N. F., Tinikashvili, N. A., Dmitrieva, T.V. (2020). Wastewater Treatment for Food Processing Industries. IOP Conference. Series: Earth and Environmental Science 459.doi:10.1088/1755-1315/459/4/04202.
13. Biyikli M., Dorak S., Asik B.B. (2020). Effects of Food Industry Wastewater Treatment Sludge on Corn Plant Development and Soil property. Poland Journal of Environmental Studies. 29(4),2565-257.
14. Dave, S., & Das, J. (2021). Technological model on advanced stages of oxidation of wastewater effluent from food industry. In *Advanced Oxidation Processes for Effluent Treatment Plants* (pp. 33-49). Elsevier. DOI: https://doi.org/10.12912/27197050/145201
15. Emodi (2021) Analysis of Industrial Effluents as They Affect the Quality of Surface Water in Enugu Nigeria. Iconic research in engineering Journal. 4(6) ISSN: 2456-8880
16. FEPA (1991). Pollution Abatement in industries and facilities Generating Wastes. Federal Republic of Nigeria Official Gazzette. 78(42). 38.
17. Habibi A., Sjaifuddin S., Pancawati J.(2024).Characteristics of Wastewater Generated by the Snack Food (Cookies) Industry. Jurnal Presipitasi 21(1),112-131
18. Haddis, A. and Devi, R. (2008). Effect of Effluent Generated from Coffee Processing Plant on the Water Bodies and Human Health in Its Vicinity. Journal of Hazardous Materials, 15(2), 259-262.
19. Havryshko M, Popovych O., Yaremko, H., Tymchuk I, Malovanyy M. (2022). Analysis of Prospective Technologies of Food Production Wastes. Ecological Engineering and EnvironmentalTechnology. 2(2):33-40.
20. Humayra, S., Hossain, L., Hasan, S. R., & Khan, M. S. (2023). Water Footprint Calculation, Effluent Characteristics and Pollution Impact Assessment of Leather Industry in Bangladesh. Water *3(15), 378*. Incident," Annual Survey of International & Comparative Law : Vol. 15: Iss. 1, Article 2.
21. Kholif, M.A., Nurhayati,1., Sugito, Sari, D.A., 2, Sutrisno J., Pungut, & Mujiyanti, D.R. (2023) Removal of BOD_5 and COD from Domestic Wastewater by Using a Multi-Media-Layering (MML) System, Environment and Natural Resources Journal 2023; 21(X), xx-xx
22. Liu B., Wang Q., Zhang Y & Chen X (2021). Study on environmental nanomaterials in food industry wastewater. IOP Conference Series: Earth and Environmental Science. 10(8), 1755-1315
23. Madu, I. E., Kamaruddin, M. A., Yusoff, M. S., Niza, N. M., Shadi, A. M. H., & Norashiddin, F. A. (2022). Emerging technologies for the management of coffee processing wastewater. *Coffee Science*, 2(2), 203-211.
24. Mangotra, A., & Singh, S. K. (2024). Physicochemical assessment of industrial effluents of Kala Sanghian drain, Punjab, India. *Environmental Monitoring and Assessment*, *196*(3), 320.
25. Morker, H., Saini, B., & Dey, A. (2023). Role of membrane technology in food industry effluent treatment. *Materials Today: Proceedings*, *77*, 314-321.
26. Mostafaie, A., Cardoso, D. N., Kamali, M., & Loureiro, S. (2021). A scientometric study on industrial effluent and sludge toxicity. *Toxics*, *9*(8), 176.
27. Nayyar, D., Nawaz, T., Noore, S., Singh, A.P. (2021). Food Processing Wastewater Treatment: Current
28. Practices and Future Challenges. In: Singh, S.P., Rathinam, K., Gupta, T., Agarwal, A.K. (eds) Pollution Control Technologies. Energy, Environment, and Sustainability. Springer, Singapore. https://doi.org/10.1007/978-981-16-0858-2_9

29. Nkwocha A.C, Ekeke,I.C, Oghame P.I (2013). Quality Assesment of Effluent Discharges from Vegetable Oil Plants. Ethiopia Journal of Environmental Sciences and Management. 16(3):23-27.
30. Nkwocha, A.C., Ekeke, I.C., Kamen, F.L., and Oghome, P.I.(2013). Quality assessment of effluent discharges from vegetable oil plant. Ethiopian Journal of Environmental Studies and Management. 6(2),24-26 http://dx.doi.org/10.4314/ejesm.v6i6.2S
31. Noukeu,N.A and Ekodeck G.E. (2016). Characterization of Effluent from Food Industries. Science direct. Open access.
32. Ogbodo, D. & Gozie, S. (2009) "Environmental Protection in Nigeria: Two Decades After the Koko
33. Incident," Annual Survey of International & Comparative Law : Vol. 15: Iss. 1, Article 2.
34. Olobaniyi, S.B and Efe, S.I.(2007). Comparison of Rainwater and Groundwater in an Oil Producing Area of Nigeria. JEHR.
35. Osho A., Mabekoje, O.O and Bello, O.O (2010). Preliminary Evaluation of Wastewater Effluents fromTwo Food Companies in Nigeria, African Journal of Microbiology Research, vol. 4(13),1395-1399.
36. OSI, (2019). How Food Producers Can Reduce Costs and Save Efficiency in their Wastewater Treatment System. Oil Skimmers Inc. www.environmental-experts.com
37. Penteado, T. Z., Santana, R. S. D. S., Dibiazi, A. L. B., De Pinho, S. C., Ribeiro, R., & Tommaso, G. (2011). Effect of agitation on the performance of an anaerobic sequencing batch biofilm reactor in the treatment of dairy effluents. *Water Science and Technology*, *63*(5), 995-1003.
38. Pervez, M. N., Mishu, M. R., Stylios, G. K., Hasan, S. W., Zhao, Y., Cai, Y., ... & Naddeo, V. (2021). Sustainable treatment of food industry wastewater using membrane technology: A short review. *Water*, *13*(23), 3450.
39. Qasim W. and Mane A.V (2013). Characterisation and Treatment of selected food industry effluents by Coagulation and Adsorption techniques. Journal of Water Resources and Industry. 10(2):2-10.
40. Odedra L.R. &Patel R.L.(2022). Food Industry Wastewater Treatment by Constructed wetlands. Journal of emerging technologies and innovative research, 6(4). 23.
41. Ratanapongleka K., Siripattanakiel S., Suannapen N., and Tummavong J. (2010). Utilization of Fermented Rice Noodles Effluents for Bio Ethanol Production. Vol. 1 no. 1. International Journal of Chemical and Environmental Engineering. 1(1), 1-15.
42. Salah-Tazdaït, R., & Tazdaït, D. (2023). Aerated Constructed Wetlands for Treatment of food industry Wastewater. In: Shah, M.P. (eds) Recent Trends in Constructed Wetlands for Industrial Wastewater Treatment. Springer, Singapore. https://doi.org/10.1007/978-981-99-2564-3_7
43. Singare P.U., Dhabarde S.S. (2013) Pollution discharge scenario of dyeing industries along Dombivali Industrial Belt of Mumbai, India. Int Lett Chem Phys Astron 22(5),48–55. https://doi.org/10.56431/p-fot249
44. Siyanbola T.O, Ajanaku K.O, James, O.O, Olugbuyiro J.A and Adekoya J.O (2011). Physico chemical Characteristics of Industrial Effluents in Lagos State, Nigeria.
45. Sperta Systems (2021). MBR (membrane Bioreactor) Solutions for Food Industry Wastewater Treatment. Sperta Membrane Systems. https://spertasystems.com.
46. Soros, A., Amburgey, J.E., Stauber, C.E., Sobsey, M.D., & Casanova, L.M. (2019). Turbidity reduction in drinking water by coagulation-flocculation with chitosan polymers. Journal of water and health, *17*(2), 204-218.
47. Tommaso, G. (2011). Effluents from the food industry. In Hygienic design of food factories (pp. 606-622). Woodhead Publishing.