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Analysis of Effluent Management among Medium and Large Scale Agro-Allied Industries in South West, Nigeria

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Abstract

The study analysed effluent management among medium and large scale agro-allied industries in South west, Nigeria. Multi-stage sampling techniques was employed in selecting 287 MLS agro-allied industries (MSAAI=222; LSAAI=65). Data for this study was obtained from primary sources using a semi-structured questionnaire. Descriptive and relevant inferential statistics such as one-way ANOVA, Pearson's chi-square test and ordinal Probit regression model were used for data analysis. The study revealed a minimum, maximum and average daily end of pipe volume of 430kg, 8000kg and 3084.21kg, respectively, for medium scale agro-allied industries and 520kg, 15,000kg and 3,534.72kg, respectively, for large scale agro-allied industries with an average proportion (53.6% and 49.0%) of medium and large scale agro-allied industries generating between 1001kg and 3000kg of effluent per day during agro-allied industrial processes. The result also indicated the quantity of end-of-pipe effluents recycled to be 436.08kg and 695.54kg for medium and large scale agro-allied industries, respectively which from the independent t-test statistics, there was a significant difference between the mean quantity of effluent recycled by medium scale agro-allied industries in comparison with the mean quantity of effluent recycled by large scale agro-allied industries ($t=12.021$; $p<0.05$). Based on comparing effluent treatment levels/systems between M&LSAI in South west Nigeria. The result revealed an average proportion (57.7%) of medium scale agro-allied industries to have disposed of their end-of-pipe without treatment, while 42.3% treated their end-of-pipe mainly through ponding or sedimentation (20.3%), aeration/membrane filtration (10.4%), chlorination and neutralisation or physicochemical treatment (4.5%) etc. By contrast, a very few proportion (15.4%) of large scale agro-allied industries disposed of their end-of-pipe without treatment, while majority (84.6%) treated end-of-pipe mainly through ponding or sedimentation (18.5%), aeration/membrane filtration (29.2%), chlorination and neutralisation or physicochemical treatment (15.4%) etc. The ordinal Probit regression model of socio-institutional predictors influencing effluent treatment level among M&LSAI in South west Nigeria showed significant variables viz: frequency of visit by waste management agency (-0.2605122 and -0.0849263); M&LSAI income (-1.94e-12 and 4.66e-14); membership of association (-0.7487836 and -0.5136997); and waste management satisfaction level (-0.2552832 and -0.1250288) respectively. The study recommended activities that increase industrial income, membership in associations and orientation on the anti-satisfaction with the status quo of effluent management to promote enhanced effluent treatment level/practices.

Keywords: Effluent; Management; Agro-allied industries; South west; Nigeria.

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1. Introduction

The primary forms of pollution that pose threats to the environment and to humans, plants, animals, and other living beings include water, air, noise, and land pollution in Nigeria [1]. According to Igwe, *et al.* [2], the contamination of water bodies can be attributed to introducing organic and inorganic industrial wastes and effluent into rivers. The primary contributors in this context encompass various industries such as paper, pulp, chemical, textile, dyeing, petroleum refineries, tanneries, and electroplating. These industries discharge substances, including dyes, detergents, acids, salts, heavy metals such as lead and mercury, pesticides, fertilizers, synthetic carbon-based chemicals, plastics, and rubber into aquatic ecosystems [3, 4].

Discharging untreated or insufficiently treated wastewater in South west Nigeria has been identified as a significant contributor to health problems and diseases. This sort of water pollution has resulted in fish mortality and the destruction of other forms of aquatic life [5]. Oketola and Osibanjo [6] opined that increased disposal of untreated/partially treated industrial wastewater were significant source of contamination and Onyegeme-Okerenta and Ogunka [7]; Adeola [8] and Ogidiolu [9] were of the view that wastewater treatment technologies may remove many of these contaminants only with the right effluent treatment technology used as well as keen considerations of treatment level, options and frequency which certain unidentified socio-institutional factors may propel.

Major studies [6, 10-21] channelled environmental pollution management from an environmental science and health management perspective revealing haphazard disposal of gaseous-chemical waste as a major determinant for the spread of gastrointestinal and parasitic diseases, untreated industrial wastewater discharged into lagoon daily resulting in high rate of water contamination, freshwater shortage and water-related diseases, solid-metal waste materials unethically discharged on fallow land, around residential houses, public space and even under the overhead bridges to mention but a few. Limiting the damages due to effluent pollution has become a challenge for the global community (Federal Ministry of Environment, 2021). In this regard, there is an urgent need to seek workable economic solutions to the problem of environmental pollution in South west Nigeria and it is clear that from the researchers' knowledge, little or nothing has been done on effluent management among medium and large scale agro-allied industries in South west, Nigeria proffering solutions to the following core research questions:

- Do end-of-pipe volume across selected states differ significantly with respect to medium and large scale agro-allied industries?
- Do effluent treatment systems differ significantly with respect to medium and large scale agro-allied industries?
- What is the effluent treatment level of medium and large scale agro-allied industries?
- What socio-institutional predictors influence effluent treatment levels among medium and large scale agro-allied industries?

2. Objectives of the Study

The broad objective of the study is the analysis of effluent management among medium and large scale agro-allied industries in South west, Nigeria. The specific objectives were to:

- compare end-of-pipe volume across selected states and compare effluent treatment systems between M&LSAI;
- ascertain effluent treatment level and estimate socio-institutional predictors influencing effluent treatment level;

2.1. Hypotheses of the Study

Based on the stated objectives, the following research null hypotheses were tested:

HO_1: there is no significant difference between effluent recycled by M&LSAI and end-of-pipe volume across selected states do not significantly differ;

HO_2: effluent treatment systems do not significantly differ among M&LSAIs;

HO_3: institutional predictors have no significant influence on effluent treatment level among M&LSAI;

3. Literature Review

3.1. End-of-Pipe Versus Process Integrated Approaches

End-of-pipe solutions are commonly recognised as control technologies that are appended to the terminal stage of the manufacturing system. According to Muo, *et al.* [22], end-of-pipe solutions can be observed as distinct entities from production processes when viewed from a systems perspective. The primary objective of employing end-of-pipe solutions is to alter the by-products remaining from manufacturing operations to mitigate their adverse impact on the natural environment, rendering them less harmful than untreated residual products. Typically, these outcomes are deemed undesirable from an economic perspective due to the adverse impact of managing the resultant wastewater sludge and wastewater on industrial viability. According to Adewolu, *et al.* [23], profit is typically generated in rare circumstances. In addition, it should be noted that implementing end-of-pipe solutions necessitates utilizing energy and raw materials, hence incurring financial expenses. The ecological implications of end-of-pipe solutions should also be subject to serious examination. While the qualitative alteration of outputs enables their disposal in accordance with existing regulations, it is important to note that end-of-pipe solutions necessitate the utilization of extra energy and resources. According to Altaf and Deshazo [24], the phenomenon above leads to a rise in the overall use of resources and energy within the sector.

Process-integrated solutions must be distinguished from end-of-pipe solutions. Process-integrated solutions encompass recycling solutions, as well as measures for process modernisation and process optimisation. The objective of process-integrated solutions is to mitigate wastewater generation throughout the production process. Typically, this encompasses the mitigation of wastewater generation and the minimization of water consumption within the industrial sector. Similar to end-of-pipe approaches, recycling solutions involve using plants or plant components that are distinctly and physically segregated from manufacturing processes [25]. In contrast to conventional end-of-pipe solutions, this particular strategy seeks to generate desired goods through impulse factors for industrial processes [26]. According to [27], the concept of "process modernisation measures" refers to enhancements made to current processes, including their management and the substitution of environmentally sustainable alternatives for existing processes. The achievement of environmental performance improvement is not feasible without implementing process modernisation procedures that involve separating the production system. According to Akinsanya [28], integrating the production process and implementing solutions to enhance environmental performance are combined into a single physical, process, and control unit.

3.2. Arguments that are used to Substantiate the Advantages of End-of-Pipe Solutions

When examining the benefits of end-of-pipe solutions in scholarly literature, the following reasons are commonly presented:

- The implementation of end-of-pipe solutions, which occur after the production process and can operate independently, has minimal or negligible impact on production [29].
- End-of-pipe technologies are considered well-established technologies that have been frequently utilised in the past and have undergone continuous enhancements [30].
- End-of-pipe solutions offer substantial legal assurance as they are recommended and acknowledged by official authorities. Based on the fundamental ideas presented, it is posited that end-of-pipe solutions are associated with a reduced number and severity of challenges during the planning, implementation, and operation stages, compared to process-integrated solutions. According to Dudley [31], end-of-pipe solutions offer greater economic benefits.

3.3. End-of-Pipe Treatment Systems

The discharge of wastewater significantly influences the natural environment, necessitating efficient treatment measures. The treatment of wastewater contributes to the preservation of various organisms dependent on it, safeguarding the planet's overall ecological balance. The contemporary way of life allows individuals to utilize a diverse range of commodities to enhance comfort and facilitate daily tasks, but with associated costs [32]. One prevalent outcome of several industrial activities is the generation of wastewater that is unsuitable for human consumption or utilisation. Fortunately, it is possible to render wastewater potable and suitable for use through wastewater treatment technologies that effectively filter and treat the wastewater, eliminating impurities such as sewage and chemicals. According to Asamoah and Amedofu [33], there are four prevalent wastewater treatment methods: physical water treatment, biological water treatment, chemical treatment, and sludge treatment.

3.3.1. Physical Water Treatment

During this phase, wastewater treatment involves the utilisation of physical techniques for purification. Various processes, such as screening, sedimentation, and skimming, are employed to eliminate solid particles. The technique does not entail the use of any chemicals. Sedimentation is a prominent method employed in physical wastewater treatment, wherein the objective is to separate insoluble or heavy particles from the wastewater [34]. After the insoluble material has undergone sedimentation and settled to the bottom, the pure water can be separated. Aeration has been identified as an additional physical water treatment strategy that is effective [35]. The procedure above involves air circulation within the water to supply it with oxygen. Filtration, as the third technique, separates and removes various impurities. Specialised filters can be employed to facilitate wastewater filtration, enabling the segregation of pollutants and insoluble particles within it. The sand filter is widely employed as the predominant filtration method. According to Chaudhry, *et al.* [36], the approach described herein offers a convenient means of effectively eliminating the grease present on the surface of some wastewater samples.

3.3.2. Biological Water Treatment

This method employs diverse biological processes to degrade the organic substances found in wastewater, including soap, human excrement, oils, and food waste. Microbial organisms engage in the metabolic breakdown of organic substances present in wastewater during biological treatment. The subject matter can be classified into three distinct areas. Aerobic processes refer to biological activities requiring oxygen to generate energy. Bacterial activity facilitates the decomposition of organic matter, resulting in the conversion of said substance into carbon dioxide, which subsequently becomes available as a source of sustenance for plants. Oxygen utilisation is observed above [37]. In the context of anaerobic operations, fermentation is employed to facilitate the decomposition of waste materials under controlled temperature conditions. According to Xia, *et al.* [38], oxygen utilisation is absent in anaerobic processes.

Composting is an aerobic treatment technique that involves mixing wastewater with carbonaceous materials such as sawdust, aiming to facilitate the decomposition and stabilisation of organic matter. The process of secondary treatment effectively eliminates a significant portion of the solid particles found in wastewater. Nevertheless, it is possible for certain dissolved nutrients, such as nitrogen and phosphorus, to persist even after this treatment stage [39].

3.3.3. Chemical Water Treatment

This therapeutic approach entails the utilization of chemical substances within a water-based medium, as implied by its nomenclature. Chlorine, a chemical with oxidizing properties, is frequently employed as a disinfectant to eradicate bacteria that contribute to water quality degradation through contaminants. Ozone is an additional oxidizing agent that is employed for wastewater purification. Neutralisation is a chemical process in which an acidic or basic substance is used to adjust the pH of the water to its inherent value of 7. According to Altaf and Deshazo [24], introducing chemicals into water inhibits bacterial reproduction, resulting in water purification.

3.3.4. Portable Chemical Solutions Neutralization Wet Processing Cart

Using a portable chemical neutralisation tank facilitates the convenient disposal of acidic and alkaline solutions. This is achieved by transferring the disposable solution to the storage tank on the cart through the implementation of a pump mechanism. After adding the solution, a separate container containing a neutralising solution is attached to the cart. A metering pump is employed to accurately measure a predefined quantity of the neutralisation solution, which is subsequently introduced into the neutralisation tank located on the cart. The solution undergoes continuous circulation and monitoring by using a pH sensor, as described by Babawuya, *et al.* [40]. The pump introduces the neutralizing solution until the pH level falls within a predetermined range. Implementing automated chemical solution neutralisation enables a contactless neutralisation process, facilitating the convenient discharge of the neutralised solution into facility wastewater treatment systems and/or municipal sewer systems. According to Jalil [41], the cart has wheels or rollers to facilitate convenient transportation to various application and disposal sites.

3.3.5. Sludge Treatment

This process involves the separation of solids and liquids, to minimize residual moisture in the solid phase and reduce solid particle residues in the separated liquid phase. One instance of this phenomenon can be observed in dewatering sludge derived from industrial wastewater or sewage treatment plants. In this context, the amount of moisture remaining in the dewatered solids plays a crucial role in determining the expenses associated with disposal, while the quality of the centrate (liquid fraction) influences the level of pollution reintroduced into the treatment facility. A centrifuge, a device commonly employed for solid-liquid separation, eliminates solid particles from wastewater [42].

4. Research Methodology

The research was conducted in the South west region of Nigeria. The South west region of Nigeria comprises six states, namely Ekiti, Lagos, Ogun, Oyo, Osun, and Oyo states. The South west region of Nigeria is situated between latitudes 60 N and 40 S, and longitudes 40 W and 60 E. It spans an area of approximately 114,271 square kilometres [43]. Multi-stage sampling techniques were employed in selecting 287 MLS agro-allied industries. The data utilised in this study were collected from primary sources by implementing a semi-structured questionnaire. The data utilized in this study was analysed by applying both descriptive and inferential statistical methods such as One Way ANOVA, Pearson Chi-Square test and Ordinal Probit regression model.

4.1. Ordered Probit Regression Model (Objective vii)

The ordered Probit regression model was used to estimate socio-institutional predictors influencing effluent treatment level**.**

4.2. Effluent Treatment Levels and Processes

This dependent variable was classified into seven groups as depicted below:

Levels	Processes/methods	Treatment levels	Treatment remarks
Level zero	Disposal (*Status Quo*)	No treatment	Poor treatment
Level one	Ponding treatment system, sedimentation	Physical treatment	Fairly poor treatment
Level two	Aeration/membrane filtration	Physical treatment	Fair treatment
Level three	Chlorination and Neutralization or physicochemical treatment	Chemical treatment	Fairly good treatment
Level four	Solid-liquid separation process	Sludge treatment	Good treatment
Level five	Composting	Biological treatment	Very good treatment
Level six	Anaerobic digestion	Biological treatment	Excellent treatment

In ordered Probit model, probabilities for M&LSAI to select one of the seven alternatives are calculated as follows:

$$Prob\ (y = 0|x) = \phi\ (-x'\beta) \qquad 3.26a$$
$$Prob\ (y = 1|x) = \phi\ (\mu_1 - x'\beta) - \phi\ (-x'\beta) \qquad 3.26b$$
$$Prob\ (y = 2|x) = \phi\ (\mu_2 - x'\beta) - \phi\ (\mu_1 - x'\beta) \qquad 3.26c$$
$$Prob\ (y = 3|x) = \phi\ (\mu_3 - x'\beta) - \phi\ (\mu_2 - x'\beta) \qquad 3.26d$$

$$Prob\ (y = 6|x) = 1 - \phi\ (\mu_6 - x'\beta) \qquad 3.26e$$

In order for the probabilities to be positive 0< $\mu 1 < \mu 2$ ……… <$\mu 6$ condition must be realised. Here, Φ is the cumulative normal distribution function. The model is solved through the maximum likelihood method. To determine the effects of explanatory variables on probabilities, marginal effects are needed to be estimated. Marginal effects of seven probabilities can be estimated using the following equations with the help of derivation [44].

$$\frac{\partial Prob\ (y=0|x)}{\partial x} = \phi(x'\beta)\beta \ldots\ldots 3.27a$$

$$\frac{\partial Prob\ (y=0|x)}{\partial x} = [\phi(-x'\beta)\beta - \phi(\mu_1 - x'\beta)]\beta \ldots\ldots 3.27b$$

$$\frac{\partial Prob\ (y=0|x)}{\partial x} = [\phi(\mu_1 - x'\beta)\beta - \phi(\mu_2 - x'\beta)]\beta \ldots\ldots 3.27c$$

$$\vdots$$

$$\frac{\partial Prob\ (y=6|x)}{\partial x} = \phi(\mu_5 - x'\beta)\beta \ldots\ldots 3.27d$$

Here δprob/δx is the derivation of probability based on x. ϕ is the cumulative normal distribution function and estimation of the ordered maximum likelihood of *β, x.* Dependent variable of the study was the effluent treatment levels among MLS agro-allied industries.

4.3. Model Explicit Statement

Y = Effluent treatment level (ordinal variable: shall consider M&LSAI highest level of effluent treatment)

β1-β10 =estimated parameters

α=threshold

X_1= age of M&LSAI (continuous variable: Years);

X_2 =frequency of visit by state's waste management agency (discrete variable: number of visit per year for waste disposal billing);

X_3= monthly agro-allied industrial income (continuous variable: Naira);

X_4= industrial location (categorical variable: 1=urban; 2= peri-urban; 3=rural);

X_5 =awareness level of treatment options (ordinal variable: high awareness = 4, medium awareness = 3, low awareness = 2, no awareness =1);

X_6= membership of association/industrial organisation (dummy variable; yes = 1; otherwise = 0);

X_7= formal training/conferences on environmental pollution control (count variable, number of times M&LSAI attended formal training/conferences on environmental pollution control);

X_8= waste management satisfaction level with the state's waste management authority (ordinal variable: High=3; moderate=2; low=1);

X_9= quantity of effluents generated (continuous variable: litres);

X_{10}=incidence of industrial reported diseases per month (number of disease cases reported per month)

μ=Error term

5. Results and Discussion

5.1. End-of-Pipe Volume and Comparison of Effluent Treatment Systems between M&LSAI

The end-of-Pipe is the terminal point in industrial water users' distribution systems. The end of pipe volume was necessary as it contains a high concentration of harmful elements of nitrogen and phosphorus. If not properly treated, it can pose serious environmental hazards on disposal.

5.2. M&LSAI End-of-Pipe Volume across Selected States

The descriptive statistics in Table 1 revealed a minimum, maximum and average daily end-of-pipe volume of 430kg, 8000kg and 3084.21kg, respectively, for medium scale agro-allied industries and 520kg, 15,000kg and 3,534.72kg, respectively, for large scale agro-allied industries with an average proportion (53.6% and 49.0%) of medium and large scale agro-allied industries generating between 1001kg and 3000kg of effluent per day during agro-allied industrial processes. The result also indicated the quantity of end-of-pipe effluents recycled to be 436.08kg and 695.54kg for medium and large scale agro-allied industries, respectively which from the independent t-test statistics, there was a significant difference between the mean quantity of effluent recycled by medium scale agro-allied industries in comparison with the mean quantity of effluent recycled by large scale agro-allied industries ($t=12.021$; $p<0.05$) clearly indicating that effluent recycling activities are more performed in LSAAI than in MSAAI. As such, the hypothesis that no significant difference exists between effluent recycled by M&LSAI was rejected and the alternate hypothesis was accepted. A one-way analysis of variance conducted in comparison of M&LSAI end-of-pipe volume across selected states (Lagos, Ogun and Osun states) in South west Nigeria shows a Fischer's statistic value of 0.072 ($p>0.05$), which was not significant. This implies no significant difference exists in the end-of-pipe volume generated in Lagos State, Ogun State and Oyo State between and within groups. Therefore, the null hypothesis stating that end-of-pipe volume across selected states does not significantly differ is accepted and the alternate hypothesis is rejected. According to Awomeso, *et al.* [45], the effluents generated from the agro-allied industries are mostly biodegradable. In the tannery and textile industry, the effluents are non-toxic but usually pose a serious economic setback in management as they require immediate disposal. Such immediate disposal may prompt M&LSAI to flush them into streams or canals without treatment or recycling. This assertion agreed with Abdulmumini, *et al.* [26] who believed that agro-allied industries generate substantial effluents and solid wastes with varying pollution loads, which need to be treated before disposal. According to Clench-Ass, *et al.* [46], some industries are water-intensive, producing voluminous effluents.

Table-1. One-way ANOVA comparison of M&LSAI End-of-Pipe volume across selected states in South west Nigeria

	Effluent Generated			Effluent Recycled	Lagos State	Ogun State	Oyo State
MSAAI (Litre/month)	**Frequency**	**Percentage**	**Mean Qty. Generated (kg)**	**Mean Qty. Recycled(kg)**	**(N=97)**	**(N=64)**	**(N=61)**
430 – 1000	22	10.2	3084.21	436.08	9 (9.3)	7 (10.9)	6 (9.8)
1001 – 2000	85	38.5			37 (38.1)	25 (39.1)	23 (37.7)
2001 – 3000	33	15.1			15 (15.5)	8 (12.5)	10 (16.4)
3001 – 4000	16	7.3			5 (5.2)	5 (7.8)	6 (9.8)
4001 – 5000	48	21.7			21 (21.6)	15 (23.4)	12 (19.7)
5001 – 8000	18	8.2			10 (10.3)	4 (6.3)	4 (6.6)
LSAAI (Litre/month)	**Frequency**	**Percentage**	**Mean Qty. Generated(kg)**	**Mean Qty. Recycled(kg)**	**Lagos (N=38)**	**Ogun (N=18)**	**Oyo (N=9)**
520 – 1000	6	9.1	3534.72	695.54	2 (5.3)	4 (22.2)	Nil
1001 – 2000	22	33.7			13 (34.2)	7 (38.9)	2 (22.2)
2001 – 3000	10	15.3			6 (15.8)	2 (11.1)	2 (22.2)
3001 - 4000	4	6.1			2 (5.3)	1 (5.6)	1 (1.1)
4001 – 5000	13	20.0			9 (23.7)	2 (11.1)	2 (22.2)
5001 - 6000	4	6.1			2 (5.3)	1 (5.6)	1 (11.1)
6001 – 15000	6	9.1			6 (15.8)	1 (5.6)	1 (11.1)
One Way ANOVA	**Sum of Squares**	**degree of freedom**	**Mean Square**	**F statistic**	**Sig.**	**Mean Effluent Recycled**	**P value**
Between Groups	477466.530	2	238733.265	0.072	0.930	t=12.021***	0.000
WithinGroups	724976093.938	219	3310393.123				

Source: Fieldsurvey2022.

5.3. Effluent Treatment Levels between MSAAIs and LSAAIs in South West Nigeria and Estimates on Socio-Institutional Predictors Influencing Effluent Treatment Level

5.3.1. Effluent Treatment Levels between MSAAIs and LSAAIs in South West Nigeria

Table 2 compares effluent treatment levels/systems between M&LSAI in South west Nigeria. The result reveals an average proportion (57.7%) of medium scale agro-allied industries to have disposed of their end-of-pipe without treatment, while 42.3% treated their end-of-pipe mainly through ponding or sedimentation (20.3%), aeration/membrane filtration (10.4%), chlorination and neutralisation or physicochemical treatment (4.5%) etc. By contrast, a very few proportion (15.4%) of large scale agro-allied industries disposed of their end-of-pipe without treatment, while majority (84.6%) treated end-of-pipe effluents mainly through ponding or sedimentation (18.5%), aeration/membrane filtration (29.2%), chlorination and neutralization or physicochemical treatment (15.4%) etc. The Pearson Chi-Square test of effluent treatment level comparism between M&LSAI in South west Nigeria shows Pearson Chi-square value, likelihood ratio, linear by a linear association of 130.000, 130.579 and 64.000 respectively while the McNemar-Bowker test reveals a significant difference in the effluent treatment level among medium and large scale agro-allied industries. Therefore, the null hypothesis that effluent treatment systems do not differ among M&LSAIs was rejected and the alternate hypothesis was accepted.

In accordance with the findings of Oluwatoyin, *et al.* [47], the initial stage in the effective handling of effluents, also referred to as end-of-pipe solutions, involves the reduction of pollutant load within effluents. This can be achieved by implementing measures to prevent the entry of raw materials or products into the effluent streams. Implementing a ponding treatment system, which involves the sedimentation of a highly polluting effluent stream from a low polluting stream, followed by the separate treatment of each effluent stream, has yielded superior performance in the treatment of effluents. In certain instances, the discharge from a particular agro-allied industry has the potential to serve as the primary input for other industries. For example, molasses, a highly polluting effluent, produced by the sugar mill is utilised as a primary ingredient in the fermentation business, specifically in the distillery sector, for alcohol manufacture. The membrane filtration process encompasses techniques such as Reverse Osmosis (RO), nanofiltration, ultrafiltration, and microfiltration, as Eruola, *et al.* [48] discussed. Reverse osmosis and nanofiltration are commonly employed techniques for retrieving water and other substances from effluent streams, while ultrafiltration is typically a preliminary treatment method [49]. Nanofiltration effectively eliminates contaminants while enabling salt passage via the permeate stream. Furthermore, the permeate (brine) recovery from textile dyeing effluent can be achieved by applying nanofiltration. Membrane filtering technologies have effectively removed many pollutants, encompassing color-based contaminants. In addition, the elevated operational pressure, issues related to fouling, and the need for periodic replacement of the filter media contribute to the overall costliness of the process. According to the research, most effluents exhibit a neutral pH, indicating that pH modification is generally unnecessary. However, it should be noted that pH adjustment may be required in specific cases, such as in textile industries and pulp and paper sectors, where neutralisation processes are employed. In solid-liquid separation processes, the effluent undergoes additional treatment in the primary treatment unit. This treatment involves the introduction of coagulants, such as lime, alum, and polyelectrolyte. Subsequently, the effluent is subjected to either a clariflocculator or a flocculator, followed by a settling tank. The analysis of effluent samples determines the selection of suitable coagulants and their respective concentrations as part of a treatability study. The primary treatment process facilitates decreasing the concentration of total suspended solids (TSS). Composting has been found to result in a notable decrease in concentrations of Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) [50]. However, it should be noted that the aforementioned primary treatments do not encompass the subsequent secondary treatment, specifically the aerobic biological treatment process, which further diminishes biochemical oxygen demand (BOD) and chemical oxygen demand (COD) levels in the effluent.

Anaerobic treatment (bio-methanation) appears to be promising to a very few proportion of medium (0.9%) and large scale agro-allied industries (6.2%) because the method not only facilitates reduction in the environmental pollution problem but also provides a scope for recovery and reuse the by-products (methane and manure) from the wastes. The economic implication of the result with regards to effluent waste treatment is that of low utilization of improved effluent treatment technologies, especially by medium scale agro-allied industries (57.7%) compared to their large scale agro-allied industrial counterparts and huge disposal of less environmentally safe effluents.

Table-2. Pearson Chi-Square test of effluent treatment levels between M&LSAI in South west Nigeria

Levels	**Processes/Methods**	**MSAAI**		**LSAAI**	
		Frequency	**Percentage**	**Frequency**	**Percentage**
No treatment	Disposal	128	57.7	10	15.4
Physical treatment	Ponding treatment system, sedimentation	45	20.3	12	18.5
Physical treatment	Aeration/membrane filtration	23	10.4	19	29.2
Chemical treatment	Chlorination and Neutralisation or physicochemical treatment	10	4.5	10	15.4
Sludge treatment	Solid-liquid separation process	4	1.8	4	6.2
Biological treatment	Composting	10	4.5	6	9.2
Biological treatment	Anaerobic digestion (Grade One)	2	0.9	4	6.2
Chi-Square Tests	**Value**	**Sig. (2-sided)**			
Pearson Chi-Square	130.000	0.000			
Likelihood Ratio	130.579	0.000			
Linear-by-Linear Association	64.000	0.000			
McNemar-Bowker Test	0.000		.		

Source: Field survey (2022).

5.3.2. Estimates on Socio-Institutional Predictors Influencing Effluent Treatment Level

Table 3 displays the socio-institutional factors that impact the level of effluent treatment among medium and large-scale Agro-industrial industries (M&LSAI) in the South west region of Nigeria. The ordinal Probit regression model yielded a log-likelihood of -250.20779 and -119.19372 for M&LSAIs, which were statistically significant at the 1% significance level. This suggests that the explanatory variables incorporated in the model collectively account for the variations observed in the effluent treatment level of MSAAIs within the study region. The LSAAI model, with a log-likelihood of -119.19372, demonstrates a superior fit to the data compared to the MSAAI model, which has a log-likelihood of -250.20779. The Pseudo R squared values of 0.4230 and 0.6854 suggest the model has a strong fit. The cut points can be interpreted concerning Z-scores for medium and large size agro-allied sectors, indicating whether the observation is above or below the mean. A Z-score of zero is equivalent to the arithmetic mean. A z-score of +2 denotes that the observed value is positioned two standard deviations above the mean, whereas a z-score of -2 shows that the observed value is positioned two standard deviations below the mean. The findings of the research on medium size agro-allied industries revealed that cuts 1, 2, 3, and 4 exhibited Z-scores below 2 standard deviations from the mean (-1.17, -0.50, -0.01, and 0.01, respectively), whereas cut 5 demonstrated a Z-score beyond 2 standard deviations from the mean. In the context of large-scale agro-allied industrial businesses, it is seen that cut 2, cut 3, cut 4, cut 5, and cut 6 exhibit Z-scores below 2 standard deviations from the mean (-1.88, -1.45, -0.92, 0.61, and 0.23, respectively). Conversely, cut 1 demonstrates a Z-score above 2 standard deviations below the mean.

5.3.3. Hypothesis and Post Estimation Test

The hypothesis posited that socio-institutional determinants do not significantly impact effluent treatment levels within the study area for medium and large scale agro-allied industry. The analysis revealed that socio-institutional variables substantially influenced effluent treatment levels among M&LSAI. The ordinal Probit regression model's LR statistic chi2 statistical significance was determined by the Prob > Chi2, a probability value. The LR statistic chi2 and the Prob > Chi2 were statistically significant at the 1% level ($P<0.05$). Consequently, the null hypothesis was refuted, leading to the acceptance of the alternative hypothesis. Among the ten explanatory factors used in the model, it was determined that four of these variables exhibited statistical significance at different degrees of probability in relation to M&LSAI. Four key variables have been identified as significant in the context of medium and large scale agro-allied industries. These variables are: the frequency of visits by the waste management agency, the income generated by the medium and large scale agro-allied industries, the membership status of the industries in relevant associations, and the level of satisfaction with waste management practices. The respective coefficients for these variables are as follows: -0.2605122 and -0.0849263 for frequency of visit by waste management agency, -1.94e-12 and 4.66e-14 for M&LSAI income, -0.7487836 and -0.5136997 for membership of the association, and -0.2552832 and -0.1250288 for waste management satisfaction level. Nevertheless, it was shown that the variables about medium scale agro-allied industries exhibited negative coefficients. Conversely, only the income generated from large scale agro-allied industries displayed a positive and statistically significant association with the likelihood of effluent treatment levels. The following is a concise analysis of the independent variables employed in the ordinal Probit regression model and their anticipated impact on the effluent treatment level, based on a prior expectation.

Table-3. Ordinal Probit regression model of Socio-institutional predictors influencing effluent treatment level

	Medium Scale Agro-allied Industry					**Large Scale Agro-allied Industry**				
Treatment	**Coefficient**	**Std. Err.**	**z**	**P>|z|**	**Marginal effect**	**Coefficient**	**Std. Err.**	**z**	**P>|z|**	**Marginal effect**
Age of M&LSAI	0.0062687	0.0054554	1.15	0.251	-0.0024454	-0.0045546	0.010863	-0.42	0.675	0.001051
Freq. visit by WMA	-0.2605122***	0.0772022	-3.37	0.001	0.1016247	-0.0849263***	0.1760992	-4.48	0.000	0.0195982
M&LSAI Income	1.94e-12***	5.15e-13	3.77	0.000	0.030013	4.66e-14***	4.85e-14	3.96	0.006	0.043014
Industrial location	-0.0606773	0.1039397	-0.58	0.559	0.02367	0.0212216	0.1994465	0.11	0.915	-0.0048973
Treat. awareness level	0.1621627	0.1259181	1.29	0.198	-0.063259	-0.2980198	0.225717	-1.32	0.187	0.0687732
Mem. of Association	0.7487836***	0.2059892	3.64	0.000	0.2918509	0.5136997***	0.3283326	5.56	0.008	0.1162607
Training freq. on EPC	-0.0500616	0.062785	-0.80	0.425	0.0195288	-0.1810686	0.1099673	-0.65	0.100	0.0417847
WM satisfaction level	-0.2552832**	0.1287964	-1.98	0.047	0.0995849	-0.1250288**	0.1713959	-1.93	0.026	0.0288526
Qty. of effluent gen.	0.0000542	0.0000454	1.20	0.232	-0.0000212	-0.0000334	0.0000528	-0.63	0.527	7.71e-06
Ill health cases	-0.055591	0.3586759	-0.15	0.877	0.0217865	0.1066887	0.2757017	0.39	0.699	-0.0246002
/cut1	-1.172128	0.7288933				-2.472356	1.050059			
/cut2	-0.5048518	0.7222518				-1.882192	1.024626			
/cut3	-0.0133159	0.7217056				-1.454593	1.015442			
/cut4	-0.0133159	0.7355313				-0.9207472	1.007717			
/cut5	1.442606	0.7995043				-0.6106138	1.009599			
/cut6						-0.234533	1.025706			
Number of Obs.	222					65				
LR chi2(9)	46.70					10.53				
Prob > chi2	0.0009					0.0000				
Pseudo R2	0.4230					0.6854				
Log likelihood	-250.20779					-119.19372				

Source: Field survey, 2022. *** Significant at 1%; ** Significant at 5%; * Significant at 10%

5.3.4. Frequency of Visit by Waste Management Agency

The coefficients of frequency of visit by waste management agency (-0.2605122 and -0.0849263) for medium and large scale agro-allied industries, respectively is significant at 1% and has a negative impact on effluent treatment level. With respect to the marginal effect, an additional unit increase in the frequency of visits by state waste management agency to medium and large scale agro-allied industries will reduce their effluent treatment levels by 10.2% and 1.9%, respectively. This is not in tandem with a priori expectations, which indicates that the frequency of visits by waste management agencies is positively related to effluent treatment level in the study area. This result can be explained possibly by the core intentions of states' waste management agency during their visit to medium and large scale agro-allied industries which is to make a reminder of expected future payment for waste management or express new (increased) bills for waste management. Besides, states' waste management agency disposes mainly of solid waste while treatment is channelled more to wastewater. Such a type of visit, which may be anti-improvement natured in effluent management, only encourages more spending by medium and large scale agro-allied industries to satisfy the course of the waste management agency. Such a visit may not affect M&LSAI treatment levels except if it was educational or training-oriented, thereby enabling very small diminutive possibilities to properly treat effluent, reducing treatment levels among M&LSAI in the study area. This finding does not agree with that of Eruola, *et al.* [48] whose findings showed that state waste management agency visit was an important factor motivating increased use intensity of specific improved waste management/treatment practices.

5.3.5. M&LSAI Income (Monthly)

The coefficient of income (-1.94e-12 and 4.66e-14) of medium and large scale agro-allied industries is significant at 1% and positively impacts effluent treatment level. With respect to the marginal effect, an additional unit increase in the income of medium and large scale agro-allied industries will increase the effluent treatment level by 3.0% and 4.3%, respectively. This is consistent with a priori expectations, indicating that the increased income is positively related to possibilities of increased effluent treatment. The result indicates that as the income of M&LSAI improves, the industries' probability of maintaining good environmental hygiene increases, which may improve their effluent treatment level. On the contrary, according to Eruola, *et al.* [48], low income among medium and large scale agro-allied industries adversely affects production levels and reduces agro-allied industries performance in ensuring good environmental health and sustainability. This finding aligns with previous research conducted by Hagos [51], which also observed a positive correlation between income and the demand for environmental quality improvement. As a result, it was hypothesised that income would positively and significantly impact the enhancement of treatment and effluent management. According to Aklilu [50], there is a positive correlation between high revenue levels in enterprises and their capacity to cover the expenses associated with liquid waste treatment charges or costs.

5.3.6. Membership of Association

The coefficients of membership of association (0.7487836 and 0.5136997) of medium and large scale agro-allied industries is significant at 1% and has a positive impact on effluent treatment level. With respect to the marginal effect, an additional unit increase in the frequency of product supplies among medium and large scale agro-allied industries will increase the effluent treatment level by 0.2918509% and 0.1162607%. This is consistent with a priori expectations, which indicates that the membership of agri-environmental related associations, cooperatives or social organizations is positively related to an increase in the treatment level of effluents in the study area since such membership enhances industrial production through access to resources and management skills and environmental awareness to tackle poor environmental situations [52]. The competitiveness for aesthetic environmental value among members of similar social organisation can also spur the need to keep the environment healthier. This fact was supported by Pallent [53] who said that association membership implies innovativeness among the respondents due to a lack of group dynamic effects. Associations like cooperative societies provide M&LSAI with better credit facilities, better productivity and better agriculturally based information which may ensure better allocation of resources, technical efficiency, profitability and, in turn, higher levels of effluent treatment.

5.3.7. States' Waste Management Satisfaction Level

The coefficients of waste management satisfaction level (-0.2552832 and -0.1250288) of medium and large scale agro-allied industries respectively is significant at 5% and has a negative effect on effluent treatment level. With respect to the marginal effect, an additional unit increase in the waste management satisfaction level by medium and large scale agro-allied industries will increase the effluent treatment levels by 9.9% and 2.9%, respectively. This is consistent with a priori expectations, indicating that waste management satisfaction level is negatively related to effluent treatment level in the study area. The increased satisfaction of medium and large scale agro-allied industries with a collection of waste will indirectly create a synergy between agro-industries and the States' waste management for potential direct landfilling, which possibly may deter them from making efforts to utilise better effluent treatment methods as they may feel it will be financially burdensome, unethical and not essential. In concordance, according to Taddesse and Hadgu [54], dissatisfaction with the current waste management service delivery is related to the demand for improved waste management action.

6. Conclusion and Recommendations

The study concluded that the medium scale agro-allied industries, which include food processing, textile, leather, and paper industries, play a significant role in the economic development of many countries. However, these industries also generate large volumes of untreated effluent compared to large scale agro-allied industries, which can have a detrimental impact on the environment if not properly managed. Therefore, it is essential to consider the future perspective of these industries in terms of untreated effluent and its impact on the environment. One of the major concerns with untreated effluent from agro-allied industries is its potential to contaminate water sources. These industries use large amounts of water in their production processes, and the effluent generated contains high levels of organic and inorganic pollutants. When this effluent is discharged into water bodies without treatment, it can lead to eutrophication, which is the excessive growth of algae and other aquatic plants. This can deplete oxygen levels in the water, leading to the death of aquatic animals and plants. In addition to water contamination, untreated effluent from agro-allied industries can also contribute to air pollution. Many of these industries use fossil fuels as a source of energy, which results in the emission of greenhouse gases and other pollutants such as sulfur dioxide and nitrogen oxides. These pollutants can have a significant impact on air quality and contribute to climate change. To address these environmental concerns, it is crucial for medium scale agro-allied industries to invest in effective effluent treatment systems. This will not only help in reducing their environmental footprint but also ensure compliance with environmental regulations. Effluent treatment systems can remove pollutants from the effluent before it is discharged into the environment, thus reducing its impact on water sources and air quality. Moreover, there is a need for these industries to adopt sustainable production practices that minimize the generation of effluent. This can be achieved by implementing water conservation measures, such as recycling and reusing water in production processes. It is also essential for these industries to implement cleaner production techniques, which aim to reduce the use of hazardous chemicals and promote the use of environmentally friendly alternatives. Furthermore, government regulations and incentives can play a significant role in encouraging medium scale agro-allied industries to invest in effluent treatment and adopt sustainable production practices. The Federal Government can provide tax incentives and subsidies to industries that implement effluent treatment systems and promote sustainable production. They can also enforce strict penalties for non-compliance with environmental regulations. In conclusion, the future perspective for untreated effluent from medium scale agro-allied industries must prioritize environmental sustainability. Efforts must be made to reduce the generation of effluent, invest in effective treatment systems, and promote sustainable production practices. This will not only protect the environment but also ensure the long-term viability of these industries.

Limitations of the Study

One limitation of the study with respect to effluent treatment data collection is the lack of standardized reporting and monitoring systems across different industries in the study area. This can make it challenging to compare and analyse data from different sources, leading to potential inaccuracies and inconsistencies in the data. Additionally, some industries may not have comprehensive data on their effluent treatment practices, making it difficult to assess the overall impact of untreated effluent on the environment.

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