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Research Article

Assessing Poisson and Negative Binomial Regression Models for Optimal Explanation of Socio-Institutional Factors Affecting Effluent Treatment Frequency Among Agro-Allied Industries in Southwest Nigeria

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Abstract: This study evaluates the suitability of Poisson and Negative Binomial regression models in explaining the frequency of effluent treatment among medium and large-scale agro-allied industries (M&LSAIs) in Southwest Nigeria. Using a multi-stage sampling technique, the research involved 287 agro-allied industries to assess which model most accurately fits the count data on effluent treatment frequency and to examine the impact of socio-institutional factors on this frequency. A key finding of the study is that the Poisson regression model emerged as more appropriate for the data compared to the Negative Binomial model. This conclusion is supported by the Cameron-Trivedi test, which confirmed that the Poisson model provided a better fit for the data, given its superior alignment with the observed count distribution. This highlights the Poisson model's efficacy in handling count data related to effluent treatment frequencies. The analysis also revealed significant differences in effluent treatment practices between large-scale agro-allied industries (LSAAIs) and medium-scale agro-allied industries (MSAAIs). LSAAIs, which treat their effluents more frequently with a mean interval of 3.45 months, contrast with MSAAIs, which have a mean treatment frequency of 10.16 months. The independent t-test confirmed this significant difference ($t = 2.93$, $p < 0.05$), indicating that LSAAIs manage their effluents more proactively. The study further explored the impact of twelve socio-institutional factors on effluent treatment frequency. For MSAAIs, seven factors were significant, including the marital status of managers, which negatively affected treatment frequency, while other factors like the frequency of visits by solid waste management officials and knowledge level of treatment options positively influenced it. For LSAAIs, five factors were significant, all showing positive relationships with treatment frequency, with no negative impacts observed.

Keywords: Poisson Regression, Negative Binomial Regression, Effluent Treatment Frequency, Socio-Institutional Factors, Agro-Allied Industries, Southwest Nigeria

Introduction

In statistical modeling, selecting the appropriate regression technique is critical for deriving accurate and actionable insights from complex count data. This study investigates the effectiveness of the Poisson and Negative Binomial regression models in capturing and explaining effluent treatment frequency among medium and large-scale agro-allied industries (M&LSAI) in Southwest Nigeria. Both models offer distinct methodologies, making it essential to evaluate their relative performance for handling count data. The Poisson regression model, a foundational tool in count data analysis, is suitable when the mean and variance of the count data are approximately equal. Its simplicity and applicability make it a robust choice for many scenarios. However, in practical applications, such as those involving environmental and socio-institutional data, overdispersion where the variance exceeds the mean is common. In such cases, the Negative Binomial regression model is often preferred because it includes an additional parameter to account for overdispersion [11,25]

This study employs both the Poisson and Negative Binomial models to determine their suitability for analyzing socio-institutional factors influencing effluent treatment practices. The comparative analysis aims to identify which model provides a better fit, thus offering more precise interpretations and guiding effective policy interventions and management strategies. Specifically, this methodological evaluation is applied to effluent treatment frequency in M&LSAI, focusing on how different socio-institutional factors impact these practices. Supporting the importance of model selection [11], explore the application of a zero-inflated generalized Poisson regression model, emphasizing the necessity of choosing the right model to capture count data accurately [25]. contribute context on effluent management, highlighting the relevance of robust statistical methods in understanding industry practices [9] compared various regression models with artificial neural networks for predicting microbial populations, reinforcing the value of model comparisons in accurate data analysis [22] and [14] provide insights into the optimization and advancements in effluent treatment technologies, underscoring the practical implications of accurate modeling for environmental management [17]. further highlight the importance of reliability analysis and performance evaluation in common effluent treatment plants, while [23] review modern treatment methods for industrial wastewater, aligning with the study's focus on improving environmental practices through effective data analysis. Evaluating the relative performance of the Poisson and Negative Binomial regression models is crucial for obtaining reliable insights from count data related to effluent treatment practices. This study's comparative analysis not only informs model selection but also enhances understanding of how socio-institutional factors affect effluent management, thereby contributing to more effective environmental management and policy development.

Objectives of the Study

The broad objective of the study is to evaluate and compare the effectiveness of Poisson and Negative Binomial Regression models in explaining the influence of socio-institutional factors on the frequency of effluent treatment among agro-allied industries in Southwest Nigeria. The specific objectives were to:

i. ascertain effluent treatment frequency of M&LSAI and

ii. estimate and compare the effectiveness of Poisson and Negative Binomial Regression models in identifying and quantifying socio-institutional predictors that influence the frequency of effluent treatment.

Hypothesis of the Study

Based on the stated objectives, the following research null hypothesis was tested:

HO1: There is no significant difference in the effectiveness of Poisson and Negative Binomial Regression models in explaining the influence of socio-institutional predictors on the frequency of effluent treatment among medium and large-scale agro-allied industries in Southwest Nigeria.

Research Methodology

A multi-stage sampling technique was utilized to select 287 medium and large-scale agro-allied industries (M&LSAI) in Southwest Nigeria. Initially, three states Lagos, Ogun, and Oyo, were purposively chosen based on their significant presence of high-polluting industries such as textiles, food processing, livestock production, and others. In the second stage, the agro-allied industries were stratified into medium and large-scale categories based on the number of employees. Industries with 50 to 199 employees were classified as medium scale, while those with 200 or more employees were classified as large scale. This categorization resulted in 276 medium-scale and 69 large-scale industries, forming a sample frame of 345 industries. For the final stage, an online survey sample size calculator was used, set at a 95% confidence level and a 5% margin of error, to determine the sample size. Consequently, 135 industries from Lagos, 94 from Ogun, and 70 from Oyo were randomly selected. This process led to a final sample of 222 medium-scale and 65 large-scale industries, totaling 287 industries for the study. Data for this study were obtained from primary sources with the use of semi-structured questionnaire. Objectives (i and ii) were achieved using descriptives, and Poisson cum Negative binomial regression model respectively.

Model specification

Poisson Regression model and Negative Binomial Regression Model

The Poisson regression model was used to estimate socio-institutional predictors influencing effluent treatment frequency. Poisson regression model is basically a regression model that meets the classical assumptions with only one exception. This exception is that the dependent variable assumes Poisson distribution. This is a very common distribution for the random variable having a value 0, 1, 2, 3,…n. Within the Poisson model [15,7], it is possible to obtain estimates of unknown regression parameters β0, β1, β2, βk. As with other regression in order to explain the distribution of yi or the expected value yi by the set of explanatory variables xi. Let's assume that the expected value of yi is given by

E{yi|xi} = exp{xiT β}……………………………………………………………..1

A common assumption in count data models is that, for given xi, the count variable yi has a Poisson distribution with expectation λi = exp {xi Tβ}. Thus, the probability mass function of yi conditional upon xi is given by

P{yi = y|xi} = exp{-λi} λi…………………………………………………………..2

y/ y!, y =0, 1, 2, …,n …………………………………………………………………3

where y! expresses 'y factorial'. Substituting the appropriate functional form for λi produces expressions for the probabilities that can be used to construct the log likelihood function for this model, referred to as the Poisson regression model. There is one important property of the Poisson distribution, that conditional variance of yi is equal to λi. This condition is referred to as Equi dispersion. If variance of yi is higher than λi, it implies overdispersion. It leads on the hypothesis H0: E {yi|xi} = V{yi|xi}.

The study used Cameron – Trivedi test (to tests for overdispersion). The test though did not indicate the inappropriateness of using the Poisson model, but the study went further to try the negative binomial model for comparison which allowed overdispersion, though interpretation of its regression coefficients is the same as the Poisson [12]. The Poisson distribution is a discrete probability distribution that models the probability of y events that are countable (discrete) out of n trials with the formula.

$$Pr(Y = y/\mu) = \frac{e^{-\mu}\mu^{y}}{y!} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

(yi= 0,1, 2,…………………………………………………………………….....n)

In Poisson distribution, the mean and variance are equal, and it has a single parameter μ.

The Poisson regression as a non-linear multiple regression model where the dependent variable (Y) is an observed count that follows the Poisson distribution. Thus, the possible values of Y are the non-negative integers. The Poisson Regression reports on the regression equation as well as the goodness of fit, confidence limits, likelihood and deviance. It was used to model count. In Poisson Regression, suppose that the Poisson frequency μ is determined by a set of k regression variables (the X's). The expression is.

$$\mu_I = E(Y_i) = \beta_1 + \beta_2 X_{2i} + \beta_3 X_{3i} + \cdots + \beta_k X_{ki} \ldots\ldots\ldots\ldots\ldots 5$$

β1 is the intercept while the regression coefficient β2, β3, …………, βk are unknown parameters that are estimated from the data. Hence, the Poisson Regression model for an observation 'i' is written as.

$$Y_i = \frac{\mu^{Y} e^{-\mu}}{Y!} + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

That is, for a given set of values of the independent variables the outcome follows the Poisson distribution. The model for estimation in this study is:

μi = Ln (METF) = β1 + β2Xi + β3Xi + ……………. + βnXni …………………..7

Where:

METF = Monthly Effluent Treatment Frequency (dependent and discrete variable: number of times agro-industries treated their effluents in a month; 0, 1, 2, 3….n)
X1 = age of M&LSAI managers (continuous variable: Years, (+));
X2 = sex of M&LSAI managers (dummy variable; male = 1; female = 0, (+/-));
X3 = marital status of M&LSAI managers (nominal variable: single = 1; Married = 2; widowed = 3; divorce = 4; separated = 5, (+/-));
X4 = educational level of M&LSAI managers (continuous variable: number of years spent in school, (+));
X5 = frequency of visit by state's waste management agency (discrete variable: number of visit per month for waste disposal, (+/-));
X6 = monthly agro-allied industrial income (continuous variable: Naira, (+/-));
X7 = access to credit (dummy variable; yes = 1; otherwise = 0, (+/-));
X8 = awareness level of treatment options (ordinal variable: high awareness = 4, medium awareness = 3, low awareness = 2, very low awareness =1, (+/-));
X9 = knowledge level of treatment options (ordinal variable: high knowledge = 4, medium knowledge = 3, low knowledge = 2, no knowledge =1, (+/-));
X10 = membership of association/industrial organization (dummy variable; yes = 1; otherwise = 0, (+/-));
X11 = formal training/conferences on environmental pollution control (dummy variable; yes = 1; otherwise = 0, (+));
X12 = distance of M&LSAI to residential buildings (continuous variable: Kilometres, (+/-));
μ = Error term

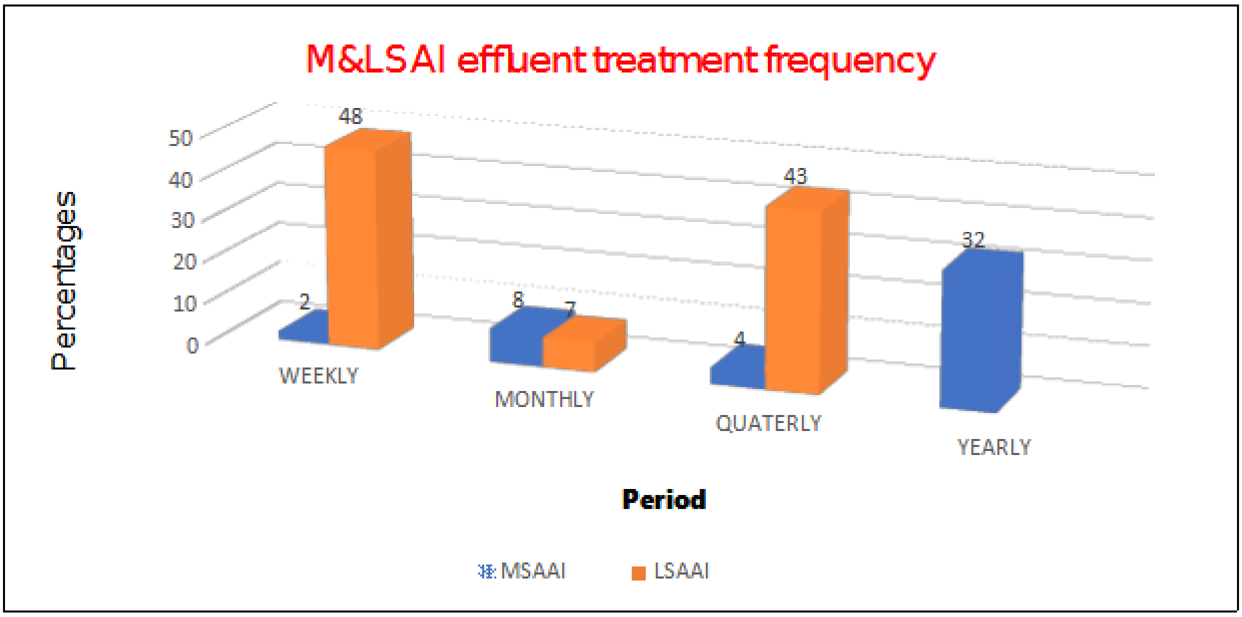
Hypothesis testing: Decision Rule: Reject Ho if P-value < α, otherwise do not reject.

Results and Discussion

Effluent treatment frequency of M&LSAI and Socio-institutional predictors influencing effluent treatment frequency

Effluent treatment frequency of M&LSAI

The bar graph presented on Figure 1 shows the effluent treatment frequency among M&LSAI in Southwest Nigeria and indicates majority (32.0%) of medium scale agro-allied industries to have treated their effluents yearly while less than 10.0% treated effluents monthly.



Mean score: MSAAI = 10.16 months; LSAAI= 3.45 months; t =2.93; p<0.05

Figure 1: Bar Graph of Effluent treatment frequency among M&LSAI in Southwest Nigeria. Source: Field survey 2023.

Majority (48.0%) of large scale agro-allied industries treated effluents weekly while 43.0% treated quarterly. This is an indication that LSAAI treat their effluents fairly earlier or more frequently prior to pollution effect emergence than their MSAAI counterparts. The mean effluent treatment frequency for medium and large scale agro-allied industries is 10.16 months and 3.45 months respectively. The independent test of significance indicated a significant difference in the effluent treatment frequency among medium and large-scale agro-allied industries (t=2.93; p<0.05) which is a confirmation that in a given year, among those who treat effluents, large-scale agro-allied industries on the average treat their effluents every three months while medium scale treats their effluent every ten months. Regular treatment of effluents prior to disposal or recycling protects the environment from harmful odour which may emanate from untreated effluents except if these untreated effluents are disposed on daily basis as they are produced.

Socio-institutional factors Influencing effluent treatment Frequency

Table 1 above shows socio-institutional factors influencing effluent treatment frequency of M&LSAI in Southwest Nigeria. Poisson and Negative Binomial regression model were tried, and the Poisson regression model was selected based on certain evident econometric reasons viz: number of significant variables, size of R squared value and the significance of the log likelihood ratio which revealed the count data was not over dispersed or zero inflated to have resulted into accepting the negative binomial regression or performing a zero inflated regression respectively.

Hypothesis and post estimation test

It was hypothesized that socio-institutional predictors have no significant influence on effluent treatment frequency among M&LSAI. From the test of the analysis, it was observed that socio-institutional predictors had significantly influenced effluent treatment frequency among M&LSAI. This was justified by the Prob (LR statistic) which is the probability value that indicates the statistical significance of the LR statistic of the Poisson regression model which were both significant at the 1% significant level (P<0.05) for M&LSAI. Therefore, the null hypothesis was rejected, and the alternate hypothesis was accepted.

To assess the appropriateness of the Poisson and Negative Binomial Regression models for explaining socio-institutional factors affecting effluent treatment frequency among agro-allied industries in Southwest Nigeria, several econometric tests and model evaluations were conducted. The Cameron-Trivedi test was employed to evaluate the dispersion of the data, specifically by examining the goodness-of-fit ratio of the Pearson χ^2 statistic in relation to its degrees of freedom. The test helps determine if the data is equi-dispersed (where the mean and variance are approximately equal), which is a key assumption for the Poisson regression model. In this case, the Cameron-Trivedi test yielded a relative variance of 0.364, which is less than 2, indicating that the data is indeed equi-dispersed. This suggests that the Poisson regression model is suitable for the data, as it assumes that the mean and variance of the dependent variable are equal. The results from the Poisson regression model were then analyzed. For both medium and large-scale agro-allied industries (M&LSAIs), the log-likelihood ratio (LR) statistics were 24.203393 for medium-scale agro-allied industries (MSAAIs) and 19.60891 for large-scale agro-allied industries (LSAAIs). Both statistics were significant at the 1% level, indicating that the explanatory variables included in the model effectively explained the variations in effluent treatment frequency among these industries. The significance at the 1% level means there is very strong statistical evidence that the model's predictors are related to the outcome variable. Moreover, the MSAAI model's log-likelihood ratio of 24.203393 was higher than the LSAAI model's ratio of 19.60891, suggesting that the Poisson model provides a better fit for the medium-scale agro-allied industries' data compared to the large-scale industries' data. This is supported by the R-squared values, which were 0.746647 for the MSAAI model and 0.504583 for the LSAAI model. The higher R-squared value for the MSAAI model indicates a better overall fit to the data, as it explains a greater proportion of the variance in effluent treatment

Out of the twelve explanatory variables included in the model, seven of the variables were found to be significant at various levels of probability for medium scale agro-allied industries, these variables: marital status of M&LSAI managers (-0.223025), frequency of Visit by SWM officials (0.207112), industrial income (2.27E-12), access to credit (0.363208), knowledge level of treatment options (0.147912), membership of association (0.429987) and environmental pollution control training (0.457181). However, only marital status of M&LSAI managers had a negative and significant relationship with the probability of effluent treatment frequency, other variables were positive and significantly related to the probability of effluent treatment frequency. For LSAAI, out of the ten explanatory variables included in the model, only five of the variables were found to be significant at various levels of probability. These variables included frequency of Visit by SWM officials (0.497994), knowledge level of treatment options (0.431948), membership of association (1.077179), educational level of M&LSAI managers (0.250633) and awareness level of treatment options (0.924977). Somewhat similar to the result obtained from MSAAI, but in this, no variable had a negative and significant relationship with the probability of effluent treatment frequency.

Marital status of MSAAI managers

The coefficient of marital status (-0.223025) of MSAAI managers was negative, strong and significant at 95.0% level. The sign of the variable is in tandem with apriori expectations. The marginal effect of marital status of MSAAI is 27.2%. This meant that married medium scale agro-allied industry managers have lesser tendency towards the frequent treatment of effluents. This therefore implies that increasing number of married medium agro-allied industrial managers increases their family responsibilities, which triggers more domestic expenditures reducing the possibilities in frequency of effluent treatment. In a different scenario, marital status of the industrial manager may enhance the early adoption (possibly induced by spouse) of sound environmental pollution management innovations. In such case, industrial managers would be more concerned with economic or income yielding environmental based technologies which would also increase industrial income, enable job level promotion and as such more personal income to take care of the spouse and family. The study also corroborated with (Akanni & Benson, 2014), who discovered that marital status had a negative effect on the preference for improved waste management attributes as a result of decline in the level of industrial production. This is due to unprecedented expenses and possibly constant income diversion which can also translate to lower disposable income hence, poor effluent waste management potential/practice [6] was of similar view that married industry managers maybe engaged in various social and economic commitments.

Such commitments include ensuring food availability for family members, better housing, education for children, clothing and acquisition of better health services which may deter them from getting fully involved in the regular treatment of effluents. Contrary [4], opined that, marriage increases responsibilities and the greater the responsibility, the higher the ambition which in the long run could lead to sourcing means for greater productivity and rewards and may lead to proper funding of effluent treatment frequently [3] also opined that the marital status of the industry managers is expected to influence the value placed on effluent waste management due to the fact that married people are likely to be more responsible to keep the environment clean and hence are more likely to make better choice for improved effluent waste management and may frequently treat their effluents.

Frequency of Visit by SWM officials

The coefficients of frequency of visit by states waste management agency (SWMA) (0.207112 and 0.497994) of medium and large scale agro-allied managers were positive and significant at 99.0% level. The sign of the variable is in tandem with apriori expectations. The marginal effect of Frequency of visit by SWM officials of MSAAI is 25.3% and 61.2%. This meant that the more the frequency of visit by states waste management agency, the better the tendency towards treatment of effluents. This therefore implies that with increasing number of visits by states waste management authorities especially for the purpose of waste management education, there may be tendency of medium and large scale agro-allied industries being more educated in the proper management of effluents so as to reduce environmental pollution. This finding is in agreement with that of [24] whose findings showed that waste management agency visit was an important factor motivating increased use intensity of improved waste management/treatment practices in Lagos State, Nigeria.

Industrial income

The coefficient of industrial income (2.27E-12) was positive and significant at 99.0% level for medium scale agro-allied industries only. The sign of the variable is in consonance with apriori expectation. The marginal effect of waste disposal satisfaction level is 0.77e-12% for MSAAI. This meant that the more the income of medium scale agro-allied industries, the higher the frequency of effluent treatment by 0.77%. This therefore implies that increasing income of medium scale agro-allied industries increases the tendency to seek for better environmental hygiene which would spur them to higher frequency in management of effluents in the study area. In concordance to the findings [10], was of the view that the income of MSAAI improves the probability of industries to maintain good environmental hygiene.

According to [13], low income adversely affects not just production level (possibly as a result of low capital investment) but reduces agro-allied industrial performance in ensuring good environmental health and sustainability. Similarly, studies by [20,5] indicated income to have positive effect in the proper management of waste in industries using adequate modern technologies and may also have positive effect in their preference for better waste management system and frequency in waste management.

Access to credit

The coefficient of access to credit (0.363208) was positive, strong and significant at 95.0% level for medium agro-allied industries. The sign of the variable is in tandem with apriori expectation. The marginal effect of access to credit is 0.4112276. This meant that the more credit access medium scale agro-allied industries have, the more the frequency of effluent treatment by 41.0%. This therefore implies that increasing the access to credit of medium scale agro-allied industries aids to meet operational expenditure to the fullest while embracing environmental satisfaction in terms of environmental hygiene, treatment of waste, utility of improved systems of waste managements and increased frequency in the treatment of effluents. This relationship indicates that higher frequency in effluent treatment is more likely propelled by better credit access. Similar results have been obtained by [17] who discovered that credit access positively influenced effluent treatment. The study is also consistent with economic theory that indicates that access to credit is positively related with demand for better environmental quality. This also indicates that environmental good is a normal good since its demand increases with credit access and this is in conformity with the work of [18].

Industrial income

The coefficients of knowledge level of treatment options (0.147912 and 0.431948) were positive, strong and significant at 99.0% level for both medium and large scale agro-allied industries. The sign of the variable is in tandem with apriori expectations. The marginal effect of knowledge level is 0.1804523 and 0.5311149 for M&LSAI respectively. This meant that the more the knowledgeable medium and large scale agro-allied industries are of the treatment options, the more their frequency of effluent treatment by 18.0% and 53.0% respectively. This therefore implies that increasing knowledge level of medium and large scale agro-allied industries with respect to treatment options also increases their understanding of the importance of effluent waste management, health implications of improperly managed effluent waste, effluent treatment modalities and long-term economic benefit of cleaner and odourless environment which would trigger higher frequency in effluent treatment as industry managers might have acquired the necessary information to keep the environment clean and to ensure the work environment is conducive for industrial business. The following study [26] have obtained similar effect attributing increase of knowledge level to the media. The media's role in environmental education is important because it is through newspapers, magazines, radio, and television that people gain both awareness and knowledge and how to deal with effluents effectively.

Membership of association

Also, the coefficients of membership of association (0.429987 and 1.077179) were positive, strong and significant at 99.0% level for both medium and large scale agro-allied industries. The sign of the variable is in tandem with apriori expectations. The marginal effect of membership of association is 0.5914838 and 0.448223 for M&LSAI respectively. This meant that membership of association especially cooperative societies increases the tendency for effluent treatment among medium and large scale agro-allied industries by 59.0% and 45.0% respectively. This therefore expresses the necessity of belonging to an association (cooperative) which develops a synergy of growth and development by pooling resources to achieve common good as well as enhancement in more informal environmental education that may ignite regular or frequent treatment of industrial effluents.

Table 1: Poisson and Negative Binomial Regression of Socio-institutional factors influencing effluent treatment frequency of M&LSAI in Southwest Nigeria

Poisson Regression	**Medium Scale Agro-allied Industry**					**Large Scale Agro-allied Industry**				
Variable	**Coefficient**	**Std. Error**	**z-Statistic**	**Prob.**	**ME(dy/dx)**	**Coefficient**	**Std. Error**	**z-Statistic**	**Prob.**	**ME(dy/dx)**
Constant	1.300602	0.447449	2.906706	0.0037		3.316982	0.849176	3.906121	0.0001	
Age of M&LSAI managers	-0.000873	0.005121	-0.170531	0.8646	-0.0010654	-0.014938	0.010481	-1.425324	0.1541	-0.0183679
Sex of M&LSAI managers	0.050201	0.116734	0.430047	0.6672	0.0611548	-0.089774	0.217068	-0.413577	0.6792	-0.1120348
Marital status of M&LSAI managers	-0.223025***	0.078699	-2.833898	0.0046	-0.2720893	-0.167893	0.144264	-1.163793	0.2445	-0.2064379
Educational level of M&LSAI managers	-0.027537	0.043242	-0.636814	0.5242	-0.0335953	0.250633**	0.107096	2.340253	0.0193	0.3081731
Frequency of Visit by SWM officials	0.207112***	0.050538	4.098162	0.0000	0.2526755	0.497994***	0.116096	4.289488	0.0000	0.6123245
Industrial income	2.27E-12***	3.63E-13	6.256095	0.0000	0.77e-12	6.84E-14	4.11E-14	1.663532	0.0962	0.42e-14
Access to credit	0.363208**	0.156976	2.313783	0.0207	0.4112276	0.066037	0.258433	0.255528	0.7983	0.0815014
Awareness level of treatment options	0.101570	0.085295	1.190806	0.2337	0.1239146	0.924977***	0.180005	-5.138623	0.0000	0.137335
Knowledge level of treatment options	0.147912***	0.055723	2.754414	0.0079	0.1804523	0.431948***	0.095517	4.522193	0.0000	0.5311149
Membership of association	0.429987***	0.136083	3.159742	0.0016	0.5914838	1.077179***	0.266707	4.038808	0.0001	0.448223
Environmental Pollution Control training	0.457181***	0.108997	4.194423	0.0000	0.557759	0.078945	0.190217	0.415029	0.6781	0.0970698
M&LSAI Distance to residential buildings	-0.003663	0.033863	-0.108175	0.9139	-0.0044691	0.124313	0.082307	1.510347	0.1310	0.1528526
R-squared	0.746647					0.504583				
Adjusted R-squared	0.703393					0.390256				
Log likelihood	24.203393***					19.60891***				
Negative Binomial Regression										
Constant	1.621979	0.828033	1.958835	0.0501		3.498594	1.066719	3.279772	0.0010	
Age of M&LSAI managers	-0.001404	0.008448	-0.166232	0.8680	-0.0010363	-0.016404	0.011897	-0.078861	0.1679	-0.0300528
Sex of M&LSAI managers	0.049104	0.216040	0.227290	0.8202	0.0764557	-0.079475	0.245977	-0.323099	0.7466	-0.0245293
Marital status of M&LSAI managers	0.283768	0.159158	0.082936	0.0746	0.3081832	0.176696	0.166618	0.060486	0.2889	0.3177294
Educational level of M&LSAI managers	-0.050030	0.073029	-0.685079	0.4933	-0.0542715	-0.247344	0.115272	-0.145738	0.0319	-0.1713788
Frequency of Visit by SWM officials	-0.282398***	0.101627	-2.778761	0.0055	-0.3441333	-0.516828***	0.139666	-3.700456	0.0002	-0.9289815
Industrial Income	-2.30E-12***	6.41E-13	-3.585596	0.0003	-0.0000135	0.71E-14	4.46E-14	1.005744	0.1321	0.74e-06
Access to credit	-0.373786	0.277498	-1.046987	0.1780	-0.4712262	0.022073	0.305557	0.072239	0.9424	-0.6995281
Awareness level of treatment options	0.060591	0.150670	0.402145	0.6876	0.0974885	-0.963203***	0.224647	-4.287623	0.0000	-0.412415
Knowledge level of treatment options	0.137082	0.111004	0.234933	0.2169	0.00930235	0.429908***	0.106412	4.040042	0.0001	0.2031021
Membership of association	-0.444174	0.266747	-0.665148	0.0959	-0.6744756	-1.102367***	0.301751	-3.653238	0.0003	0.566339
Environmental Pollution Control training	-0.510948***	0.199822	-2.557022	0.0106	-0.6287634	0.091713	0.214718	0.427130	0.6693	0.1551674
M&LSAI Distance to residential buildings	-0.005439	0.070629	-0.077004	0.9386	-0.0330412	0.113881	0.093780	0.214347	0.2246	0.1290302
R-squared	0.708793					0.488358				
Adjusted R-squared	0.663365					0.370287				
Log likelihood	-344.2615**					-99.54015**				
Cameron-Trivedi test (Relative variance)	*0.364<2*									

Source: Field survey, 2022. *** Significant at 1%; ** Significant at 5%; * Significant at 10% (Cameron-Trivedi test==equi-dispersed).

Environmental Pollution Control training

The coefficient of environmental pollution control training (0.457181) was positive, strong and significant at 99.0% level for medium scale agro-allied industries. The sign of the variable is in line with apriori expectations. The marginal effect of environmental pollution control training is 0.557759. This meant that the more environmental pollution control training medium scale agro-allied industries receive, the more the effluent treatment frequency by 56.0%. This therefore implies that increasing training in environmental pollution control for medium scale agro-allied industries is a strong motivating factor as it aids in increasing their awareness, knowledge, waste management consciousness and effluent treatment potentials. Medium scale agro-allied industries may change their environmental pollution behaviour when their values, beliefs, and pro-environmental norms change. Improved education on environmental pollution control as well as increased environmental literacy may ignite such changes. Environmental literacy for MSAAI means developing and participating in the social practices likely to change the way MSAAI managers think about and act upon ecological-environmental issues. Environmental literacy obtained through environmental pollution control training is a powerful tool that contributes a great deal to thinking through the question of what one can contribute for a more just and sustainable way of life for a rapidly deteriorating planetary environmental community [8].

Educational level of managers

The coefficient of educational level (0.250633) was positive, strong and significant at 95.0% level for large scale agro-allied industries. The sign of the variable is in consonance with apriori expectations. The marginal effect of educational level is 0.3081731. This meant that the more educated managers of large scale agro-allied industries are, the more the frequency of treatment of effluents by 31.0%. This confirms the findings of [8] that level of education attained is one of the major factors that positively and significantly influenced industrial business management capabilities which may in turn reduce environmental externalities. Therefore, the high literacy levels of the MSAAI would enable them to better utilize effectively and efficiently available resources and enhance more environmentally friendly practices such as increased frequency of effluent treatment and ensuring better environmental pollution management. Furthermore [19], hypothesized that the higher the level of education, the more industrialists would appreciate the consequences of mishandling waste and the more value the individual would give in order to avoid the risk of being a victim of unclean environment [2]. reiterated the fact that education relates to a better understanding of the problem of organic waste and its management [1]. The expectation is that formal education increases the level of understanding of the respondents on the consequences of unsanitary disposal of effluent waste. This provides chances for the individual to have a formal choice to participate more in effluent treatment/waste management

Awareness level of treatment options

The coefficient of awareness level of treatment options (0.924977) was positive, strong and significant at 1% level for large scale agro-allied industries. The sign of the variable is in tandem with apriori expectations. The marginal effect of awareness level of treatment options is 0.137335. This meant that the more the awareness level of treatment options by large scale agro-allied industries, the better the frequency of effluent treatment by 14.0%. Awareness level by large scale agro-allied industries means having proximal or preliminary understanding on dealing with effluents generated. Environmental awareness relates to the recognition by the public, environmental issues and values, and the implications they have in relation to economic issues and social standards of living. Public environmental education and applied communications are the key tools for expansion and effective delivery of awareness campaigns to different types of audiences. Nevertheless [8], was of the view that increase in awareness level of treatment options drives better effluent treatment leading to increased frequency in the treatment of effluents. Therefore, awareness to waste regulations of 2015 were expected to have negative effect to open dumping, burning and burying especially if untreated.

Conclusion and Recommendations

The study concludes that the Poisson regression model is more suitable than the Negative Binomial model for analysing effluent treatment frequency among agro-allied industries in Southwest Nigeria. This conclusion, confirmed by the Cameron-Trivedi test, indicates that the Poisson model provides a better fit for the count data. Additionally, the study highlights the significant role of socio-institutional factors such as managerial characteristics, regulatory visits, and knowledge of treatment options in influencing effluent management practices.

These findings emphasize the importance of considering socio-institutional dynamics when developing policies and strategies to improve environmental management in agro-allied industries. Based on the conclusion, here are three recommendations:

i. Given the Poisson regression model's superior fit for count data on effluent treatment frequency, it is recommended that researchers and policymakers utilize this model for analyzing similar environmental data. This approach will provide more accurate insights into treatment practices and help tailor interventions effectively.
ii. To improve effluent management practices, it is essential to address the key socio-institutional factors identified in the study. This includes increasing the frequency of regulatory visits, providing training and resources on effluent treatment options, and supporting managerial staff through capacity-building initiatives. Such measures can lead to more consistent and effective effluent treatment across agro-allied industries.
iii. Policymakers should design and implement targeted interventions that address the specific socio-institutional factors influencing effluent treatment practices. This could involve creating incentives for industries to engage in regular treatment, enhancing access to technical and financial resources, and fostering collaboration between industries and regulatory bodies. By focusing on these factors, policies can be more effectively aligned with the needs of agro-allied industries, leading to improved environmental outcomes.

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