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PREDICTION OF FIVE-DAY BIOCHEMICAL OXYGEN DEMAND (BOD_5) FROM SOME POLLUTION PARAMETERS IN POULTRY AND BREWERY WASTEWATERS.

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Abstract

The five-day biochemical oxygen demand (BOD_5) is a principal pollution indicator used by monitoring agencies for proof of compliance with environmental standards in monitoring and management of wastewater discharges. In this research, poultry and brewery wastewaters were characterized for some pollution potentials. Results obtained were used to relate BOD_5 with some pollution parameters such as total suspended solids (TSS), permanganate value (PV) and chemical oxygen demand (COD) present in these wastewaters using correlation and regression analysis. The aim was to attempt to predict BOD_5 from these measures of contamination (i.e. TSS, PV, and COD) which are also oxygen dependent and readily determinable for quick and effective wastewater monitoring. Significant relationships were obtained from the analysis. Results obtained from the linear regression equations and coefficient of correlations were: TSS/BOD_5 ($y = 1.093x + 30.58$; $r = 0.984$), BOD_5 / TSS ($y = 0.885x – 17.45$; $r = 0.984$), PV/BOD_5($y = 0.9777x + 54.7$; $r = 0.983$), BOD_5 /PV($y = 0.9876x – 43.22$; $r = 0.983$), BOD_5 / COD($y = 1.4753x + 26.12$; $r = 0.982$), COD/BOD_5 ($y = 0.6532x – 3.91$; $r = 0.982$) for the poultry wastewater. Also for the brewery wastewater relationships obtained were: TSS/BOD_5 ($y = 0.921x + 31.00$; $r = 0.934$), BOD_5/ TSS($y = 0.9477x + 24.00$; $r = 0.934$), PV/BOD_5($y = 1.0499x + 44.45$; $r = 0.934$), BOD_5 /PV($y = 0.83x + 8.77$; $r = 0.934$), BOD_5/ COD($y = 1.5635x+28.52$; $r = 0.980$),COD/ BOD_5($y = 0.6145x – 1.1045$; $r = 0.980$) respectively. Confidence intervals (CI) for the relationships established for the linear regressions of BOD_5 on TSS, BOD_5 on PV, and BOD on COD were: BOD_5 on TSS = $1.02 \le a \le 1.17$ at 95% and $0.99 \le a \le 1.20$ at 99%, BOD_5 on PV = $0.85 \le a \le 2.81$ at 95% and $1.62 \le a \le 3.65$ at 99%, COD on BOD_5 = $1.40 \le a \le 1.55$ at 95% and $1.36 \le a \le 1.59$ at 99% for the poultry wastewater. Also for the brewery wastewater, confidence intervals were: BOD_5 on TSS = $0.86 \le a \le 0.98$ at 95% and $0.83 \le a \le 1.01$ at 99% , BOD_5 on PV = $0.94 \le a \le 1.16$ at 95% and $0.89 \le a \le 1.21$ at 99%, and COD on BOD_5 = $1.51 \le a \le 1.62$ at 95% and $1.48 \le a \le 1.65$ at 99% respectively.The functional relationship found to exist between BOD_5 and the three parameters (TSS, PV and COD) were expressed by the following equations: (i) BOD_5= 1.09 TSS + 30.58 (ii) BOD_5 = 0.98 PV + 54.70 and (iii) COD = 1.48 BOD_5 + 26.12 for the poultry wastewater ; (i) BOD_5 = 0.92 TSS + 31.00 (ii) BOD_5 = 1.05 PV + 44.45 and (iii) COD = 1.56 BOD_5 + 23.28 respectively for the brewery wastewater. Results obtained show that BOD_5 can be predicted from TSS, PV, and COD, in both wastewaters. The study will be useful for effective monitoring and wastewater analysis as it will facilitate effluent assessment for management decision.

Keywords: Prediction, BOD_5, pollution parameters, TSS, PV, COD, correlation, regression analysis, poultry wastewater, brewery wastewater.

1.0 INTRODUCTION

Environmental pollution is a worldwide problem which has been known since antiquity. Recently pollution problems have become more recognized. Pollution occurs when the true nature of a substance (water, fluid etc) is adversely impaired by the introduction of other substances into it [1].

Currently, Nigeria is faced with serious pollution problems. Increased urbanization leading to industrial revolution has greatly accelerated the release of many pollutants to the environment. Oil industries release pollutants from oil exploration and production, the brewery industries release huge amounts of organic pollutants into nearby rivers due to carbohydrates and proteins contained in raw materials for brewing beer. Recently increased awareness on white meat consumption has triggered the growth of poultry industries. Typically wastewater from poultry farms contains organics, vitamins and minerals. Enormous amount of water is utilised for industrial activities. Due to increased industrial

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activities there has been serious environmental degradation and increased pollution load to surface waters, soil and agricultural lands [2].Most of these wastewaters are discharged indiscriminately into receiving surface waters. Pollution arising from diverse activities in some industries has drastically affected these rivers. There has been steady accumulation of pollutants! Natural processes may no longer be able to cleanse the aquatic environment because of the enormous amounts of pollutants generated and discharged into these receiving water bodies on daily basis. For this reason, wastewater monitoring and treatment before disposal becomes necessary. The ultimate goal is to protect the environment in a manner agreeable to public health requirements [3, 4].

There are huge side effects resulting from generation and disposal of related wastes. However several monitoring measures and regulatory agencies are being put in place to minimize pollution in the environment both domestically and industrially in order to ensure pollution free and hence disease-free environment.

The five-day BOD (BOD_5) is the principal test applied to a water sample (i.e. surface water, wastewater and treated effluents) to determine its strength in terms of oxygen required for biological oxidation of organic matter present in five days. BOD_5 test has been the most widely accepted method of evaluating environmental pollution [5, 6, 7]. It measures the oxygen required to stabilize organic matter present in a sample of water by biochemical action in five days. It is also a chemical procedure for determining how fast biological organisms use up oxygen in a body of water [8].

Total suspended solids (TSS) are insoluble organic and inorganic particles present in water.TSS measures the degree of pollution. [9, 10].

Permanganate value (PV) measures the amount of potassium permanganate ($KMnO_4$) required to oxidize all oxidizable substances present in a water sample. In the presence of an acid, $KMnO_4$ acts on easily available suspended solids. PV therefore provides information about how much suspended solids are present in the water sample.

Chemical oxygen demand (COD) provides a measure of the oxygen equivalent of the portion of the organic and inorganic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant. Therefore, COD measures the rate of oxygen uptake as a result of chemical oxidation process in a sample of water. It is a rapidly measured pollution characteristic related empirically to BOD_5

Oxygen requirement in a water sample therefore is an indirect measure of BOD_5, COD and PV values of the sample [11].

Although BOD_5 test is the most widely accepted measure of organic pollution, it takes five days to obtain results which can quickly be carried out in three hours by the COD method.

Different alternative methods have been developed by researchers in an attempt to shorten the long period problem to a few days [12,13]. Reliable empirical correlations have been established in some cases between BOD_5 and other pollutants in domestic and industrial wastewaters [14, 6, 15].

In water quality assessment, adoption of rapid measures of appraisal has become an area of interest to both environmental managers and monitoring agencies.

This study focuses on quick prediction of BOD_5 values from TSS, PV or COD in poultry and brewery wastewaters for rapid assessment of organic load in wastewater treatment plants, where quick determinations of these parameters are required by workers for any urgent operation. Knowledge of TSS, PV and COD values which take only a few hours to determine and then correlate with BOD_5 will give room for a quick prediction of the corresponding BOD_5 values from the relationship existing between them.

2.0 MATERIALS AND METHODS

2.1 Sources of wastewater samples

The poultry wastewater samples were obtained from a poultry farm located in Jeddo near Warri town, Delta State Nigeria. The poultry farm was a medium sized one stocking 10,000 birds.

The two major departments in the farm were the broiler and layer sections.

The broiler section, a raring house which operated a deep litter system while the layer section operated the battery cage system. In this system laying birds are confined throughout their productive life in small cages. The total amount of wastewater generated per day was 2.5×10^4 litres. The source of the wastewater was from the flushing of the fowl droppings scrubbing of floor, drains and washing of trays and troughs used for feeding the fowls.

The water which flowed into the drainage system was finally discharged through a drainage into a septic tank.

The brewery wastewater was obtained from a brewery factory located in Benin City, Edo State, Nigeria. The brewery factory is a large one and it produces about 7.4×10^4 litres of beer products daily. The main products of the factory are classic beer and malt.

The amount of raw wastewater generated daily was 1.91×10^5 litres. There are several steps in the brewing process which include barley washing and steeping, malting, fermenting, conditioning, filtering and packaging.

The various source of the wastewater in the factory were from malt preparation, fermentation processes and bottling of products. The wastewater arising from malt-house was obtained during barley washing and steeping. During steeping process, water soluble substances such as polysaccharides (capable of undergoing ready hydrolysis) saccharose, glucose, pectin, mineral salts and albuminous compounds (fibrin and legumin) from the husks diffused into the water. The colour produced was yellowish-brown and the wastewater displayed a tendency toward putrefaction. All the wastewater from the storage, cellars, bottling and bottle washing plants and equipment washing process were passed into an effluent tank from where it is channelled through pipe into a nearby river.

2.2 Sample Collection

Poultry wastewater samples were obtained during routine poultry flushing and washing

While brewery wastewater samples were collected from a pipe conveying all the effluents out of the brewery works.

Both poultry and brewery wastewater samples were collected on hourly basis for 11 hours beginning at 7am and ending at 6pm. The day for sample collection in the new week was different from that of the preceding week. This was done so that the total exercise might account for the cyclic and intermittent variations occurring at the work site. Each sample was collected in a clean well labelled plastic bottle and preserved in the refrigerator maintained at 4^0C. For each sampling the rate of flow was measured. At the end of each sampling period, the samples were mixed together in volumes proportional to the rates of flow. This mixture was the composite sample that was analyzed for the pollution parameters. All together (48) composite samples (24 for each type of wastewater) were obtained and used for analysis.

2.3 Sample Analysis

All samples were analyzed as directed in the Standard Methods for the Examination of Water and Wastewater [16] together with Standard Methods for Water and Effluents Analysis [11] and Methods of Sampling and Test for Water and Wastewater [17]. pH and temperature were determined using the Hach pH/ISE meter Model 50125.

The suspended solids were determined gravimetrically at an oven temperature of 103^oC-105^0C. Glass fibre filter paper was used for filtration. PV was determined by titrimetric method while COD was determined using dichromate digestion method (closed reflux) using a COD reactor.

The BOD_5 was analysed using sodium azide modification of Winkler's method.

Results obtained were subjected to correlation and regression analysis for the purpose of assessing any significant relationship that may exist between BOD_5 and other parameters (TSS, PV, and COD) in the various wastewaters. The methods used for sample analysis is as summarised in Table 1.

Table1. Sample Analysis Method.

Physico-chemical parameters	*Analytical method*
pH	Electrometric method.
Temperature	Electrometric method.
Total Suspended Solids(TSS)	Gravimetric, Residue drying at 105^0C
Permanganate Value (PV)	Titrimetric method
Chemical Oxygen Demand(COD)	Potassium dichromate, Closed reflux method
Biochemical Oxygen Demand(BOD)	5 days incubation at 20^0C

2.4 Working Hypothesis

BOD_5 was correlated with TSS, PV and COD by the general equations:

BOD5= aTSS + b (1)

BOD5 = a PV + b (2)

COD = a BOD + b (3)

Where "a" and "b" are constants and the parameters BOD_5,TSS, PV and COD are variables. Equations (1) and (2) were considered for the relationships between BOD_5, TSS and PV where BOD_5 represents y axis and PV or TSS represents x axis. Equation 3 was considered for the relationship between BOD_5 and COD where COD represents y axis and BOD_5, x axis. This is because studies have shown that COD values are usually higher than BOD values. [1, 15]. Therefore, let COD represent dependent variable, y and BOD_5, the independent variable, x.

The functional relationships between x and y were therefore determined by the correlation coefficient and linear regression model [18, 19]. The estimate of the correlation index termed 'correlation coefficient r, is given by:

$$r = \frac{\sum xy - \frac{\sum x \sum y}{n}}{\sqrt{\left(\sum x^2 - \frac{(\sum x)^2}{n}\right)\left(\sum y^2 - \frac{(\sum y)^2}{n}\right)}} \quad (4)$$

Also in relation to the correlation model the t distribution for small sample size with n-2 degrees of freedom was calculated under the null hypothesis (r = 0) where:

$$t = r\sqrt{\left[\frac{n-2}{1-r^2}\right]} \quad (5)$$

Thus the null hypothesis was tested with the observed and calculated values and the value of the correlation coefficient judged significant at chosen probability levels (95% and 99%) respectively.

Using the regression analysis the regression of (i) BOD_5 on TSS, PV or (ii) COD on BOD_5 as the case may be were given by :

$$y = ax + b + \sigma(a) \quad (6)$$

where:

$$a = \frac{\sum x\,y - \frac{\sum x \sum y}{n}}{\sum x^2 - \frac{(\sum x)^2}{n}} \quad (7)$$

$$b = \frac{\sum y - a\ \sum x}{n} \quad (8)$$

σ (a) represents the mean square errors and sum of squares.

For accurate prediction of y, the mean square errors and sum of squares were also calculated :

$$\sigma\ (a) = \pm\sqrt{\frac{\frac{\sum y^2 - b\sum y - a\sum xy}{n-2}}{\Sigma(\ x - \bar{x})^2}} \quad (9)$$

For the null hypothesis, a = 0 and the alternative hypothesis, a ≠ 0, the confidence intervals were obtained by the equation:

$CI = a - \sigma(a) \times t\,(1-{}^{\alpha}/_{2}:n-2) \le a \le a + \sigma(a) \times t\,(1-{}^{\alpha}/_{2}:n-2)$ (10)

Therefore the correlation coefficient was judged as significant at 95% and 99% confidence intervals and the confidence coefficient for the value of "t" at n-2 degree of freedom was: $t\,(1-{}^{\alpha}/_{2}:\ n-2)$ [18, 19].

3.0 RESULTS AND DISCUSSION

This chapter represents the results of the analysis carried out on the two types of wastewater samples. It also discusses the results obtained in the course of this study.

Table 2. Results of Physico - Chemical Analysis of the Poultry and Brewery Wastewaters.

S/No	Parameter	Poultry wastewater		Brewery wastewater	
		Range	Mean ± SD	Range	Mean ± SD
1	Temperature (^{o}C)	24.90 - 27.90	26.46	28.40 - 36.20	31.43
2	pH	6.56 -7.82	168.59	6.64 - 9.80	7.89
3	Total Suspended Solids, TSS (mg/L)	219.5 6 - 382.11	302.65 ± 56.86	308.10 - 582.20	419.78 ± 64.44
4	Permanganate Value, PV (mg/L)	221.6 - 411.90	313.65 ± 63.48	248.50 - 409.00	355.40 ± 56.48
5	Biochemical Oxygen Demand, BOD_5 (mg/L)	280.00 - 445.00	361.37 ± 63.16	300.10 - 536.00	417.61 ± 63.52
6	Chemical oxygen Demand, COD (mg/L)	433.00 - 688.00	559.25 ± 94.13	487.00 - 870.40	681.44 ± 101.33

SD = standard deviation

Results in Table 2 are a summary of the characteristics of the wastewaters obtained from the analysis together with their mean and range of values. Results obtained for temperature and pH are also shown in the table. For the poultry wastewater values of TSS ranged from 219.56 to 382.11mg/L and the mean value was 302.65± 56.86 mg/L. PV values ranged from 221.66 to 411.90mg/L with a mean value of 313.65± 63.48 mg/L. BOD_5 values also ranged from 280.00 to 445.00 mg/L with a mean of 361.37± 63.16mg/L while COD values ranged from 433.00 to 688.00 0.33mg/L with a mean value of 559.25± 94.13mg/L.

TSS values for the brewery wastewater were in the range of 308.10 to 582.20 with a mean value of 419.78± 64.44mg/L. PV values were in the range of 248.50 - 409.00 mg/L with a mean of 355.40± 56.48 mg/L.BOD_5 values ranged from 300.10 to 536.00 mg/L the mean value was 417.61± 63.52 mg/L and COD values ranged from 487.00 - 870.40 mg/L with mean value of 681.44± 101.33 mg/L. The general trend observed was COD> BOD_5> PV > TSS. The High COD and BOD_5 values show that the wastewaters contain high levels of biodegradable organic matter. The higher values of COD compared with BOD_5 values may be due to the fact that the BOD_5 test measured the oxygen demand of biodegradable pollutants whereas the COD test measured the oxygen demand of both biodegradable and non-biodegradable oxidizable pollutants. This means that COD could yield more accurate result than BOD_5. Thus in situations where BOD_5 values may be inhibited by toxicants or other factors, knowledge of COD will give room for accurate prediction of the BOD_5 values when a relationship is established between them. The higher values of COD compared with PV values was because COD is based on dichromate oxidation which has superior oxidizing ability compared with oxidation by potassium permanganate chemical oxidant [20]. The TSS values obtained present the amount of undissolved organic and inorganic substances present in the various wastewater samples. Also result of the permanganate value obtained reveals the amount of total suspended solids in the water samples. These TSS values reveal the amount of oxygen that will be required to stabilize the wastes in the water samples. This amount of oxygen could be obtained through BOD measurement.

Table 3. Values Obtained from the Statistical Analysis for r, $t_{(observed)}$, a, b, σ (a) and CI at $t_{0.95}$ and $t_{0.99}$

S/N	Parameter pairs for BOD_5 prediction	r	(t) observed	a	B	σ (a)	$t_{0.95}$ CI	$t_{0.99}$ CI
1.	Raw poultry Wastewater							
	BOD_5 / TSS BOD_5 / PV COD / BOD_5	0.984 0.983 0.982	25.80 25.00 24.27	1.09 0.98 1.48	30.58 54.70 26.12	± 0.04 ± 1.06 ± 0.05	$1.02 \le a \le 1.17$ $0.85 \le a \le 2.81$ $1.40 \le a \le 1.55$	$0.99 \le a \le 1.20$ $1.62 \le a \le 3.65$ $1.36 \le a \le 1.59$
2.	Raw brewery wastewater							
	BOD_5 / TSS BOD_5 / PV COD / BOD_5	0.934 0.934 0.980	12.25 12.14 23.28	0.92 1.05 1.56	31.00 44.45 22.50	± 0.04 ± 0.06 ± 0.03	$0.86 \le a \le 0.98$ $0.94 \le a \le 1.16$ $1.51 \le a \le 1.62$	$0.83 \le a \le 1.01$ $0.89 \le a \le 1.21$ $0.48 \le a \le 1.65$

Table 3 present values of correlation coefficient r, the observed t-distribution, slope, intercept, errors associated with the slope and confidence intervals of the linear equations obtained from the regression analysis.

The relationships established between BOD_5 and each of these pollution parameters are as shown in Figures 1a and 1b, 2a and 2b, 3a and 3b, 4a and 4b, 5a and 5b and also 6a and 6b respectively.

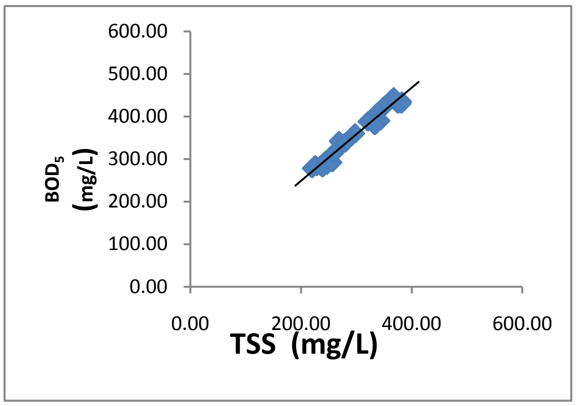

Figure 1a: Regression analysis of BOD_5 on TSS in poultry wastewater

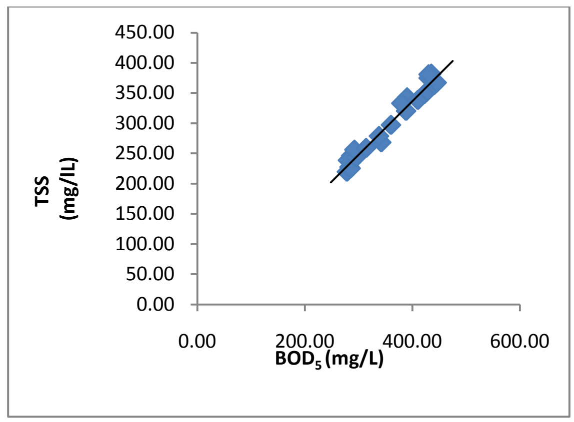

Figure 1b: Regression analysis of TSS on BOD_5in poultry wastewater

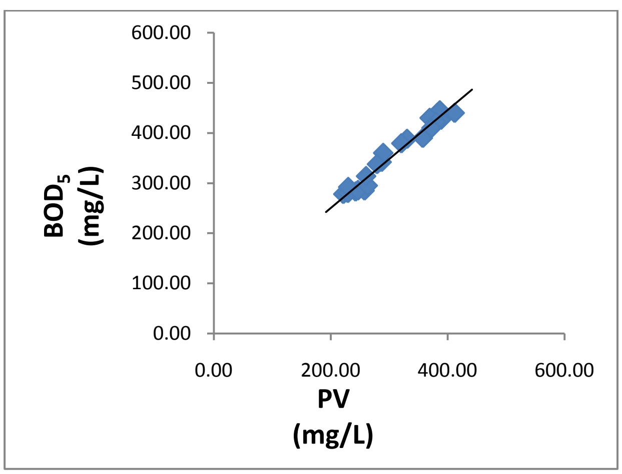

Figure 2a: Regression analysis of BOD_5 on PV in poultry wastewater

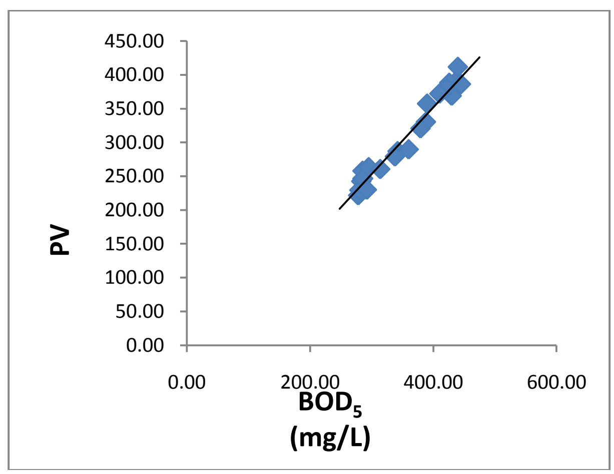

Figure 2b: Regression analysis of PV on BOD_5 in poultry wastewater

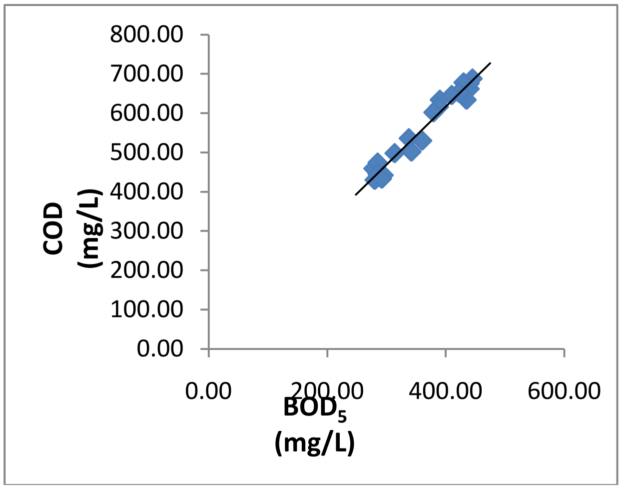

Figure 3a: Regression analysis of COD on BOD_5 in poultry wastewater

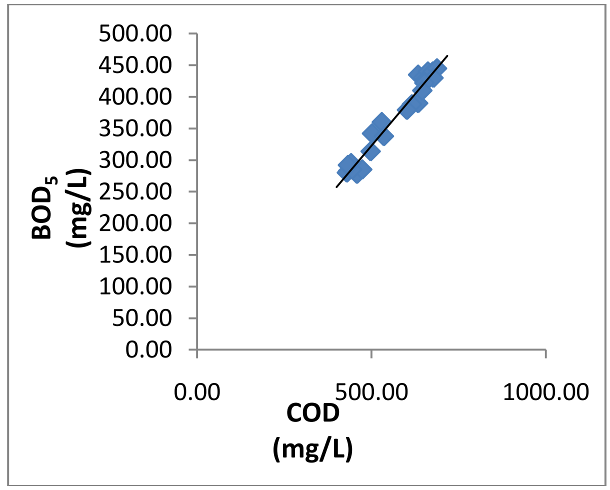

Figure 3b: Regression analysis of BOD_5 on COD in poultry wastewater

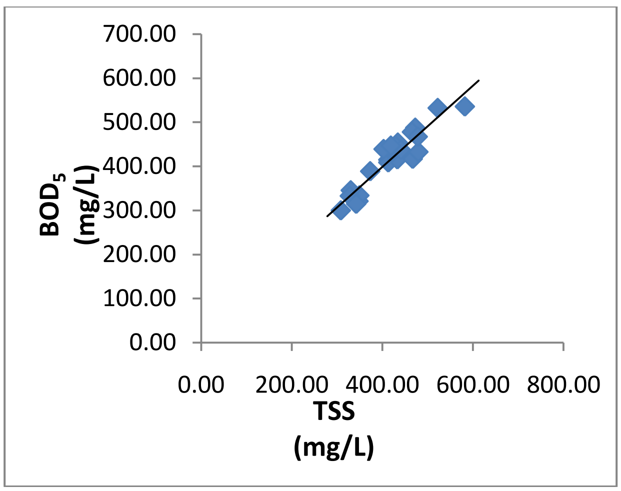

Figure 4a: Regression analysis of BOD_5 on TSS in brewery wastewater

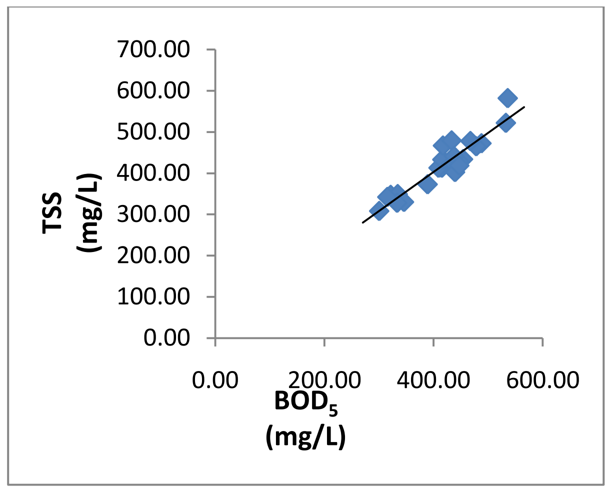

Figure 4b: Regression analysis of TSS on BOD_5 in brewery wastewater

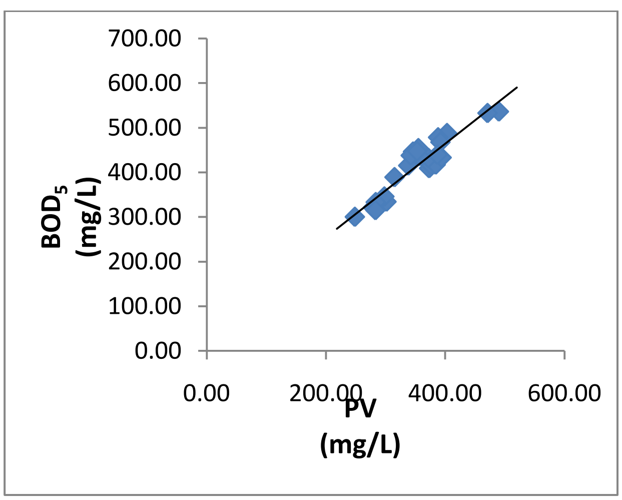

Figure 5a: Regression analysis of BOD_5 on PV in brewery wastewater

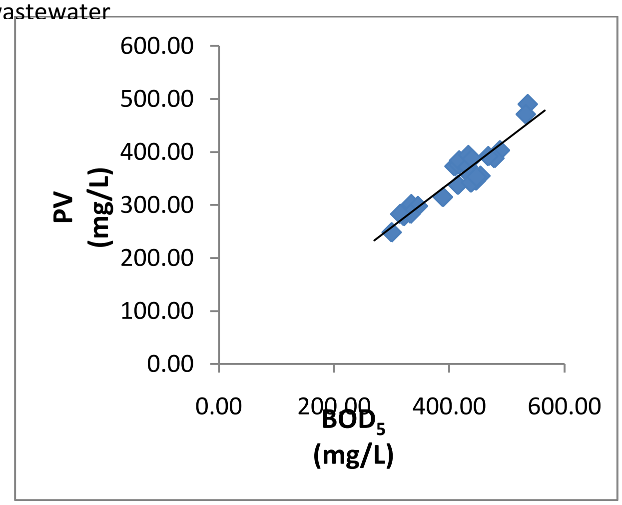

Figure 5b: Regression analysis of PV on BOD_5 in brewery wastewater

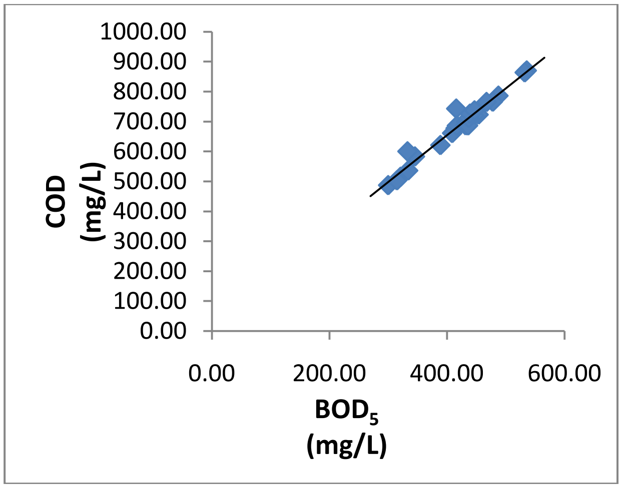

Figure 6a: Regression analysis of COD on BOD_5 in brewery wastewater

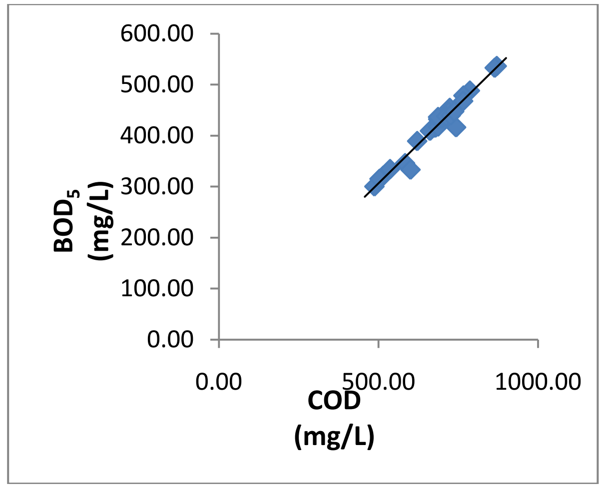

Figure 6b: Regression analysis of BOD_5 on COD in brewery wastewater

Results obtained from the linear regression equations and coefficient of correlations for poultry wastewater (i.e. Figures 1a and 1b, 2a and 2b, 3a and 3b) were:
BOD_5/TSS ($y = 0.885x – 17.45$; $r = 0.984$)
TSS/BOD_5 ($y = 1.093x + 30.567$; $r = 0.984$)
BOD_5/PV ($y = 0.9876x – 43.223$; $r = 0.983$)
PV/BOD_5 ($y = 0.9777x + 54.7$; $r = 0.983$)
BOD_5/COD ($y= 1.4753x + 26.115$; $r = 0.982$)
COD/BOD_5 ($y = 0.6532x – 3.9108$; $r = 0.982$)
Also for the brewery wastewater (i.e. Figures 4a and 4b, 5a and 5b, and 6a and 6b) results obtained were:
BOD_5/TSS ($y = 0.9477x – 24.01$; $r = 0.934$)
TSS/BOD_5 ($y = 0.921x + 30.998$; $r = 0.934$)
BOD_5/PV($y = 0.83x + 8.7764$; $r = 0.934$)
PV/BOD_5($y = 1.0499x + 44.452$; $r = 0.934$)
BOD_5/COD ($y = 0.6145x – 1.1045$; $r = 0.980$)
COD/BOD_5 ($y = 1.5635x+ 28.519$; $r = 0.980$)
The regression plots shown in Figures 1b, 2b, 3b, 4b, 5b and 6b were used to validate the plots in Figures 1a,2a,3a,4a,5a and 6a respectively using the same data.
Confidence intervals were:
Poultry wastewater:
BOD_5/TSS = $1.02 \leq a \leq 1.17$ at 95% and $0.99 \leq a \leq 1.20$ at 99%,
BOD_5/PV = $0.85 \leq a \leq 2.81$ at 95% and $1.62 \leq a \leq 3.65$ at 99%,
COD/BOD_5 = $1.40 \leq a \leq 1.55$ at 95% and $1.36 \leq a \leq 1.59$ at 99%

Brewery wastewater:
BOD_5/TSS = $0.86 \leq a \leq 0.98$ at 95% and $0.83 \leq a \leq 1.01$ at 99%,
BOD_5/ PV = $0.94 \leq a \leq 1.16$ at 95% and $0.89 \leq a \leq 1.21$ at 99%,
COD/BOD_5 = $1.51 \leq a \leq 1.62$ at 95% and $1.48 \leq a \leq 1.65$ at 99% respectively.

3.1a Correlation and regression of BOD_5 / TSS for raw poultry wastewater
The regression plot of BOD_5 versus TSS for raw poultry wastewater is as shown in Figures 1a and 1b. Considering the regression plot of BOD_5 on TSS (Figure 1a), where TSS on x axis is the independent variable and BOD_5 on y axis is the dependent variable. The correlation coefficient, r_1 was 0.984, $(t_1)_{observed}$ was 25.80, $(t_1)_{calculated}$ was 1.72 and 2.51 at 95% and 99% probability levels. The values of r_1 and $(t_1)_{observed}$ here showed that there was a significant relationship between BOD_5 and TSS for poultry wastewater.
For correlation to exist, the value r should lie between -1 and +1; i.e. the r values are such that $-1 \leq r \leq +1$.For positive correlation, r values lie between + 0.01 and + 1.0 and for negative correlation r values lie between 0.01 and -1.0 [21]. Also the slope a_1 was 1.09 and intercept b_1 was 30.58; error associated with the slope $\sigma(a_1)$ was calculated and the value was ±0.04.Confidence intervals obtained were:

$1.02 \leq a \leq 1.17$ at 95% and $0.99 \leq a \leq 1.20$ at 99% .
The value of the slope of the graph of BOD_5 versus TSS was 1.09. Therefore at 95% and 99% confidence intervals, it was estimated that the slope would assume a value between the intervals of 1.02 and 1.17 and 0.99 and 1.20 respectively.
The intercept of the graph on BOD_5 axis was 30.58 at TSS = 0. The significance of this value was that the poultry wastewater contained this amount of biodegradable organics. It was therefore concluded that the relationship between BOD_5 on TSS for raw poultry wastewater was real, strong and significant at 95% and 99% confidence levels. The resulting linear equation was:

$$BOD_5 = 1.09\ TSS + 30.58 \qquad (11)$$

When SS = 200mg/L:
$BOD_5 = (1.09 \times 200 + 30.58)$ mg/L
$BOD_5 = 248.58$mg/l

3.1b Correlation and regression of BOD_5 / PV for raw poultry wastewater.
Figures 2a and 2b show the relationship between BOD_5 and PV for raw poultry wastewater. Using Figure 2a (regression of BOD_5 on PV) r value was 0.983, $(t_2)_{observed}$ was 25.00, $(t_2)_{calculated}$ were 1.72 and 2.51. The value of the correlation coefficient, r_2 was 0.983. This was significant because $(t_2)_{observed}$ which was 25.00 was greater than $(t_2)_{calculated}$ at 95% and 99% confidence levels respectively.

Therefore the relationship between BOD_5 and PV for raw poultry wastewater was strong and well correlated. The slope, $a_2 = 0.98$, $b_2 = 54.70$, error associated with the slope, $\sigma(a_2)$ was ±1.06 and the confidence intervals were:
$0.85 \leq a \leq 2.81$ at 95% and $1.62 \leq a \leq 3.65$ at 99%. The value of the slope of the graph (BOD_5 versus PV) was a_2= 0.98. Therefore the slope would assume a value between 0.85 and 2.81 and 1.62 and 3.65, at 95% and 99% confidence intervals respectively.

The intercept of the graph b_2, was found to be 54.70mg/L at PV= 0. This value was large and it signifies that there was an increase in the amount of biodegradable organic present in the raw poultry wastewater for that period.
Therefore it was concluded that the relationship between BOD_5 and PV for raw poultry wastewater was real, strong and significant at 95% and 99% confidence intervals. The resulting linear equation was:

$$BOD_5 = 0.98\ PV + 54.70 \qquad (12)$$

When PV = 250mg/L
Then $BOD_5 = (0.98 \times 250 + 54.70)$ mg/L
$BOD_5 = 299.70$mg/L

3.1c Correlation and regression of COD / BOD_5 for raw poultry wastewater.
Figures 3a and 3b show the relationship between COD and BOD_5 for raw poultry wastewater. From Figure 3a, r_3= 0.982, $(t_3)_{observed}$ = 24.27, $(t_3)_{calculated}$ = 1.72 and 2.51 at 95% and 99% probability levels. The r_3 value was significant since $(t_3)_{observed}$ was greater than $(t_3)_{calculated}$ at 95% and 99% probability levels. Also $a_3 = 1.48$, $b_3 = 26.12$, $\sigma(a_3) = \pm0.05$ and confidence intervals were:
$1.40 \leq a \leq 1.55$ at 95% confidence intervals and $1.36 \leq a \leq 1.59$ at 99% confidence intervals respectively. The value of the slope of the graph was 1.48. Thus at 95% and 99% confidence intervals, the slope would assume a value between the intervals of 1.40 and 1.55 and 1.36 and 1.59 respectively.
On the COD axis, the intercept of the graph was found to be 26.12mg/L at zero BOD_5. The significance of this value was that the treated domestic sewage contained this amount of non-biodegradable organic matter.
Hence, it was concluded that the relationship between COD and BOD_5 for raw poultry wastewater was real, strong and significant at the confidence levels of 95% and 99%.

Therefore the linear regression equation for the wastewater was:

$$COD = 1.48\ BOD_5 + 26.12 \qquad (13)$$

When COD = 600mg/L

$$BOD_5 = \left(\frac{600 - 26.12}{1.48}\right) mg/L$$

$$BOD_5 = 387.76 mg/L$$

3.1d Correlation and regression of BOD_5 on TSS for raw brewery wastewater
Figures 4a and 4b represent the correlation between BOD_5 and SS for raw brewery wastewater. From Figure 4a, the r_4 was 0.934, $(t_4)_{observed}$ was 12.25, $(t_4)_{calculated}$ was 1.72 and 2.51 at 95% and 99% intervals.
The correlation coefficient, r_4 = 0.934 was significant. The observed t distribution, $(t_4)_{observed}$ = 12.25 was also greater than the calculated t values i.e. $(t_4)_{calculated}$ which were 1.72 and 2.51 at 95% and 99% probability levels.

Therefore the relationship between BOD_5 and SS for brewery wastewater was strong and well correlated. The slope, $a_4 = 0.92$, $b_1 = 31.00$ $\sigma(a_4) = \pm0.04$ and the confidence intervals = $0.86 \leq a \leq 0.98$ at 95% confidence intervals and $0.83 \leq a \leq 1.01$ at 99% confidence intervals respectively.

The magnitude of the slope of the graph of BOD_5 versus SS found to be 0.92 was positive. It was found that the slope would assume a definite value within the intervals 0.86 and 0.98 at 95% confidence intervals and 0.83 to 1.01 at 99% confidence intervals. The intercept on the BOD_5 axis was 31.00mg/l at SS=0. The significance of this value was that the brewery wastewater contained this amount of biodegradable organic matter.

Thus it was concluded that the relationship between BOD_5 and SS for brewery wastewater was real, strong and significant at 95% and 99% confidence levels. The linear regression equation for the wastewater was:

$BOD_5 = 0.92\ SS + 31.00$ (14)

When SS = 300mg/L

$BOD_5 = (0.92 \times 300 + 31.00)$ mg/L

$BOD_5 = 307$mg/L

3.1e Correlation and regression of BOD_5 on PV for raw brewery wastewater

The regression plot of BOD_5 versus PV for the raw brewery wastewater is as shown in Figures 5a and 5b.

Considering Figure 5a, $r_5 = 0.934$, $(t_5)_{observed} = 12.14$. The correlation coefficient r_5 was 0.934, it was significant. Also the observed t-distribution, t_5 was 12.14. This was greater than $(t_5)_{calculated}$ whose values were 1.72 and 2.51 at 95% and 99% probability levels. Thus the relationship between BOD_5 and PV was strong and well correlated. Here also, $a_5 = 1.05$, $b_5 = 44.45$, $\sigma(a_5)$ ±0.06 and the confidence intervals were:

$0.94 \le a \le 1.16$ at 95% and $0.89 \le a \le 1.21$ at 99%.

The magnitude of the slope of BOD_5 versus PV was found to be 1.05 and was positive. It was found that the slope would assume a definite value within the intervals 0.94 and 1.16 and 0.89 and 1.21 at 95% and 99% confidence intervals respectively.

The graph had an intercept on the BOD_5 axis with the value 44.45 at PV = 0. The significance of this value was that the brewery wastewater contained that amount of biodegradable organics.

Hence it was concluded that the relationship between BOD_5 and PV for the brewery wastewater was real, strong and significant at the confidence levels of 95% and 99%. Thus the linear regression equation for the wastewater was:

$BOD_5 = 1.05\ PV + 44.45$ (15)

When PV = 400mg/L

Then $BOD_5 = (1.05 \times 400 + 44.45)$ mg/L

$BOD_5 = 464.45$mg/L

3.1f Regression of COD on $BOD_5$for raw brewery wastewater.

Figures 6a and 6b depicts the correlation between COD on BOD_5 for brewery wastewater. Considering the regression of COD on BOD_5 (Figure 6a) the correlation coefficient, r_6 was 0.980, $(t_6)_{observed}$ was 23.28 while $(t_6)_{calculated}$ was 1.72 and 2.51 at 95% and 99% Confidence levels. The values of r_6 and $(t_6)_{observed}$ here showed that there was a significant relationship between COD and BOD_5 for the brewery wastewater.

Also, a_6 was 1.56 and b_6 was 22.50, $\sigma(a_6)$ was ±0.03 and the confidence intervals were:

$1.51 \le a \le 1.62$ at 95% confidence intervals and $1.48 \le a \le 1.65$ at 99% confidence intervals respectively. The value of the slope of the graph of COD versus BOD_5 was 1.56. Therefore at 95% and 99% confidence intervals, it was estimated that the slope would assume a value between the intervals of 1.51 and 1.62 and then 1.48 and 1.65.

The intercept of the graph on the COD axis was 22.50 at $BOD_5 = 0$. The significance of the value was that the brewery wastewater contained this amount of non-biodegradable organics.

It was therefore concluded that the relationship between COD on BOD_5 for raw brewery wastewater was real, strong and significant at 95% and 99% confidence levels. The resulting linear equation was:

$COD = 1.56\ BOD_5 + 22.50$ (16)

When COD = 700mg/L

Then $BOD_5 = \left(\frac{700 - 22.50}{1.56}\right)$ mg/L

$BOD_5 = 434.29$mg/L

4.0 CONCLUSION.

Strong positive correlations were observed for the relationship which exist between BOD_5 and the parameters studied (i.e. TSS, PV, and COD). Also, the difference between the calculated values (using the predicted equations) and the values obtained from analysis was (within the limit of experimental error) ± the intercept of the predicted equations. Therefore, BOD would be predicted from these parameters (mentioned above) in poultry or brewery wastewaters using equations 11-16. These equations could also be re-written by adding ± to the intercept such as:

BOD_5 =1.09 TSS ± 30.58 (17)
BOD_5= 0.98 PV ± 54.70 (18)
COD = 1.48 BOD_5 ± 26.12 (19)
BOD_5 = 0.92 SS ± 31.00 (20)
BOD_5= 1.05 PV ± 44.45 (21)
COD =1.56 BOD_5 ± 22.50 (22)

The results obtained reveal that approximate amounts of oxygen necessary to stabilize organic matter both biologically and chemically in water samples can be estimated from values of some pollution characteristics such as total suspended solids, permanganate values and chemical oxygen demand. Such tests can be carried out within few hours rather than five-day BOD_5 test. This finding will serve as a very useful tool in the control and monitoring of treatment plant processes. It will also serve as a very useful and quick measure to be employed for any urgent operation needed to protect public health and the entire environment.

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