

# Efficiency Assessment and Mathematical Correlations Development between Bod and Other Parameters in Jalandhar Sewage Treatment

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**ABSTRACT :** For sixteen weeks wastewater treatment in sewage treatment plant at Jalandhar, Punjab was considered for present studies. Sixteen waste water samples were collected at different stages of treatment units and analyzed for the major water quality parameters, such as biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS) and Ammoniacal-N concentration. The performance efficiency of each unit in treating the pollutants was calculated. Percentage removal of BOD, COD, TSS and ammoniacal-N explains the satisfying overall efficiency of the plant. A mathematical correlation is established between the influent and treated effluent parameters, specifically in relation to the BOD parameter indicated the prior basis and the assessment criteria of the effluent product.

**KEYWORDS:** Wastewater treatment, sewage treatment plant, mathematical correlation, biological oxygen demand.

## I. INTRODUCTION

It's nearly two decades since UASB (Upflow Anaerobic Sludge Blanket) concept for sewage (municipal wastewater) treatment was started in India and today it has taken an edge over the other developing countries having similar climatic conditions in the use of this technology. At present, about 23 full-scale UASB plants are in operation at various places in India with total installed capacity of about 9,85,000 m<sup>3</sup>/day (985 mld) and about 20 number are in pipeline which are likely to be commissioned within next 3-4 years. It also presents the potential of UASB technology in other developing countries with its future within India as well based on the evaluation of life cycle cost (LCC). Other sewage treatment technologies were also included while evaluating LCC [1].

Worldwide presently over 200 full-scale UASB plants are in operation for the treatment of both domestic and industrial wastewaters. However, in India the UASB Process is being widely adopted for domestic wastewater and it can be claimed that 80% of total UASB reactors worldwide for domestic wastewater treatment is in India. The basic approach towards selection of technology for sewage was low capital costs, low energy requirements, low O&M costs and sustainability aspect. This was derived from the experience of Ganga Action Plan. The conventional aerobic systems were their high energy requirements, unreliable power supply situation in the states, and higher O&M costs; while those in favor of UASB were their robustness, low or no dependence on electricity, low cost of O&M [2].

Conventionally, anaerobic processes are to be used for the treatment of high strength organic wastewaters. However, typical hydro-dynamics of UASB coupled with its unique characteristic of holding high granular biomass, made it possible to apply the anaerobic processes for the treatment of low strength wastewaters.

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## II. LITERATURE SURVEY

[3] studied the physico-chemical and biological parameters of Agra city groundwater from March 1997-1998 and their values were compared to assess the seasonal variation that occurred from October to March. Parameters like pH, TDS, Total Hardness, Total Alkalinity,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{NO}_3$ ,  $\text{Cl}^-$  and Coliform showed a downward trend from April to June and increased abruptly during the rainy season i.e. July to October. The abrupt rise may be due to seepage of contaminants with rain water and geochemical deposition within the vicinity of groundwater structures that need further study. No specific trend was seen for fluoride because monsoon has little impact on fluoride of aquifers.

[4] conducted a laboratory study to monitor the groundwater quality of selected sites of Ghazipur city, Uttar Pradesh by examining various physico-chemical parameters like pH, TDS, Dissolved Oxygen, Total Hardness, Total Alkalinity, Sodium, Potassium and 14 Chlorides. The sampling was carried out in the month of April 2007 from five different sites i.e. Rauzza, Aamghat, Vishweshwar Ganj, Shastri Nagar and Gora Bazaar. It was found that the pH ranged from 6.8-8.3 whereas TDS ranges from 145-245 mg/l which was within the prescribed limits of Indian Council of Medical Research (ICMR). Calcium Hardness ranges from 99-158 mg/l and Dissolved Oxygen from 3.4-5 mg/l indicating nearly pure symptoms. A comparison with ICMR standards shows that the water is nearly fit for drinking purposes but Disinfection by-Products (DBP) analysis is recommended because of higher Dissolved Oxygen Carbon (DOC) and groundwater analysis must be done timely.

[5] carried out epidemiological survey of 110 samples in Ludhiana city which included treated source water, treated piped water and treated piped filtered water. Water samples were collected from Municipal Council supply lines of Ludhiana city. The samples of drinking water were tested according to IS-10500-1991 BIS and Bacteriological water testing kit in the months of July and August. Out of 110 drinking water samples 37 samples were bacteriological potable which included areas like Bhai Randhir Singh Nagar and Sarabha Nagar and 73 were non potable included areas Haibowal, Tajpur Road. Water samples from 40 filters were drawn and tested for bacteriological potability. A total of 80% samples were non potable after 96 hours of incubation. The potability of piped water was tested by conventional technique and result was positive. The elemental analysis of water samples was also done and found elements Al, Na, Ca, Fe, K, Mg and S were present below permissible limits. Thus researchers suggested proper chlorination and timely analysis of potential biofilm formation in pipes.

[6] an investigation was made to evaluate the extent of water pollution at Eloor, Ernakulum District, Kerala. The area was divided into four zones and total of 40 water samples from different location was collected, analyzed and correlation analysis was made. 15 Magnesium and Chloride exceeded the desirable limits in some areas. Significant positive correlation was observed between Electrical Conductivity, Total Hardness and Chloride.

[7] studied the Fluorosis Mitigation Process in Dungarpur, Rajasthan. The fluoride concentration in 17 states of India is 1-48 mg/l out of which West Bengal is at the top followed by Uttar Pradesh, Tamil Nadu, Rajasthan, Punjab, Orissa, Maharashtra and many more. Fluoride in excess of 1.0 mg/l can cause dental fluorosis, skeletal fluorosis i.e. loss of appetite, stiffness of neck. In Rajasthan 18 out of 32 districts are fluorotic which contains 2 to 20 mg/l of fluoride. Defluoridation at domestic level can be done by Nalgonda technique and Activated alum technique and popularized under the sponsorship of UNICEF.

[8] carried out a study of physico-chemical parameters and conductivity of some heavy metals such as iron, cobalt, cadmium, lead, mercury, chromium, selenium and arsenic in industrial effluent water of Okhla Industrial Area Phase-2 and then groundwater of nearby areas. The results were compared with ISI and WHO drinking water standards. The discharge of untreated effluent by the industries is leading to contamination of groundwater of surrounding areas. Lead, mercury, fluoride, TDS, sulphates was above the desirable limits.

[9] studied groundwater samples from 60 locations in Erode District, Tamil Nadu during pre-monsoon and post monsoon seasons. Groundwater samples were tested for 11 physico-chemical parameters. Water quality index was prepared which revealed that at some places water was contaminated due to high concentration of alkalinity, turbidity and magnesium.

[10] carried out the study at Rupnagar, Punjab to study the land use and land-cover change in the area and its groundwater quality. The results showed that the quantity of groundwater increased due to natural and artificial recharge due to land use and 16 cover pattern. The quality of groundwater deteriorated due to input of fertilizers for enhancing the short term soil fertility. RS-GIS were used for preparation of thematic layers.

[11] Statistical study on pre-monsoon and post-monsoon variation of groundwater level was done by collection and analysis of various parameters. It was noted that the Theni District depth to water level was not uniform in the period of

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2005-2007 and it was limited to areas having 2-5 meter below ground level (m.bgl). out of 8 blocks, 5 blocks are categorized as overburden and 3 blocks as critical.

[12] collected the groundwater samples from 20 locations in the radius of 25 km of Kaithal city.

## 2.1 Advantages and disadvantages of anaerobic treatment.

Anaerobic digestion processes have already been applied since the end of the 19th century for the stabilization of primary and secondary sludge from activated sludge processes and the treatment of night soil in septic tanks and simple biogas digesters.

Anaerobic treatment of raw domestic/ municipal sewage is, however, a more recent development which has barely found entrance into common know-how and experience, in particular in industrialized countries. Therefore, financing institutions still tend to rather transfer activated sludge systems with anaerobic sludge digestion, which are suitable for cold climates, since the bulk of the cold wastewater cannot be heated to allow for anaerobic treatment. Treatment already reach removal efficiencies of 65%, 80% and 70% for COD, BOD and TSS (total suspended solids) respectively. Joint anaerobic treatment of sludge and wastewater is attractive (given sufficient sewage temperature) due to low investment and maintenance costs, no primary clarifier required, no sludge digester required (stabilization of suspended organic matter in anaerobic reactor), low land requirements, local production of construction material and mechanical plant. Moreover it requires low demand for process energy (no energy consuming aerators): thus a considerable reduction of CO<sub>2</sub> emissions due to low consumption of fossil energy and simultaneous surplus energy production. Also reduction of CH<sub>4</sub> emissions from uncontrolled disposal/decomposition of wastewater due to the collection of the gas formed during the process, low sludge production and high sludge quality (the sludge, if not loaded with pathogens or heavy metals, can readily be applied to agricultural land) are among the key advantages of this process [13] [14].

The main disadvantages of these treatment systems include lower treatment efficiencies (about 5- 10% less than in activated sludge processes if no post-treatment is installed) while no nutrients (N, P) are removed without post treatment. The H<sub>2</sub>S content present in the gas can lead to problems with bad smell and corrosion. Compared to pond systems, a rather poor pathogen removal capacity if no post treatment is installed and an economically not feasibility to keep working sewage temperatures below 15 °C. Most of the world's anaerobic sewage treatment plants of this type have been built in countries with a large internal market like Mexico, Brazil, India, China and Colombia. Some relevant large sewage treatment plants implementing UASB technology are presently also under construction with German cooperation in Venezuela, Ecuador and Egypt.

A mathematical model (MSB Model) was set up to predict the development of the FBFs characteristics such as biofilm growth, substrates utilization, dissolved oxygen consumption, BOD loading removal, volumetric oxygen consumption rate by filter (OCF), and bead bed volume under the different conditions. This model was then calibrated with a set of bioclarification data. The model results were consistent with literature defining the relationships between dissolved oxygen consumption, BOD loading removal, and biofilm growth. This model is specifically used to predict design parameters for FBFs in municipal sewage treatment systems. The entire study was based on the following experimental parameters: OCF, dissolved oxygen (DO), hydraulic loading, BOD loading, maximum ratio of BOD removal to OCF (MX-factor) [15].

## III. MATERIALS AND METHODS

Treated and untreated samples were collected from wastewater treatment plant at Jalandhar, Punjab under closely controlled and maintaining similar conditions. The plant receives about 100 MLD of sewage daily of inhabitants, hospitals and institutions. Wastewater before any treatment and after biological treatment inclusive of disinfection was analyzed for total suspended solids (TSS), Ammoniacal-N, biochemical oxygen demand (BOD) and chemical oxygen demand (COD) using standard methods [2]

### 3. 1 Analysis

Both physico-chemical and bio-chemical analysis were carried out using for both the untreated i.e. raw wastewater and after primary secondary sewage treatments. Analysis for total suspended solid (TSS), ammoniacal-N, biological oxygen demand (BOD) and chemical oxygen demand (COD) were conducted using the standard methods [16]. All statistical analyses of data obtained from pilot plant tests were conducted using a regression analysis method [17] and Microsoft Excel spreadsheets. The confidence levels were set at 95%.

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## IV. RESULTS AND DISCUSSION

### 4.1 BOD analysis

BOD is basically a bacterial bioassay test that provides an estimate of the biodegradability of the organic content of the wastewater. Typical raw sewage (wastewater) has a BOD in the 180 to 220 mg/L range and the prescribed limit lies below 30 mg/L. Results of this analysis before wastewater treatment and after anaerobic treatment are shown in table-1 and figure-1 shows the final comparison analysis of the samples before (B) and after (A) treatment. Variation of BOD (A) i.e. BOD value after anaerobic treatment of wastewater with that of BOD (B) i.e. BOD value of raw wastewater (before treatment) is mentioned in equation-1. This equation is the sole outcome after the regression analysis of the obtained BOD values.

$$\text{BOD(A)} = 0.196 \text{ BOD(B)} - 6.256 \quad - (1)$$

Table-1 BOD levels before and after treatment.

Sample No.	Before Treatment (mg/l)	After Biological Treatment (mg/l)
	BOD-B	BOD-A
1.	165	26
2.	165	26
3.	170	27.2
4.	166	26.5
5.	165.5	26.2
6.	166.5	26.5
7.	166	27
8.	167.5	27.5
9.	166.5	26
10.	165	26
11.	169	27
12.	170	27.2
13.	166	26.5
14.	166.5	27
15.	170	27.5
16.	169	26

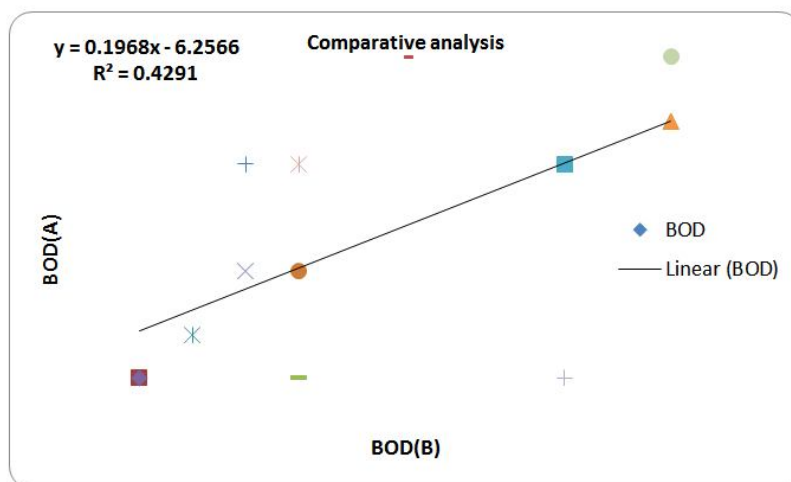


Figure-1 Comparative BOD analysis of the status of the before and after treatment of 16 wastewater samples.

### 4.2 COD analysis

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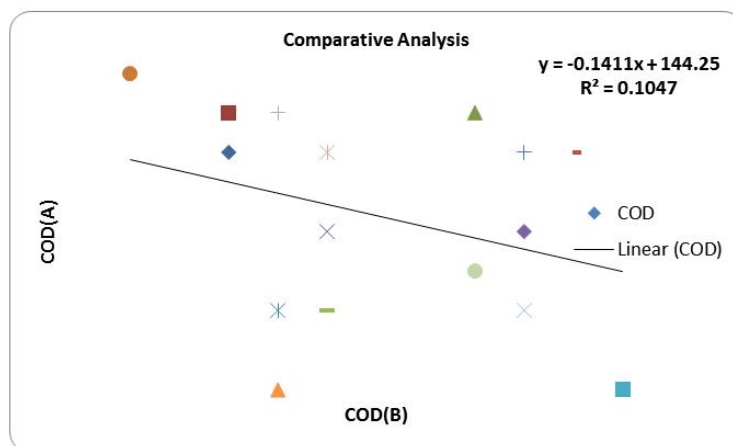
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COD is a much more severe test that uses chemicals, e.g. acids, and heat, to digest and oxidize both organic and inorganic compounds that are in the wastewater. COD should always be greater than BOD for the same sample. Since BOD is a measure of the biodegradability of the wastewater the ratio of BOD to COD can help further assess the type of biological treatment that is appropriate. Typical raw sewage (wastewater) has a COD in the 500 to 600 mg/L range and the prescribed limit lies below 250 mg/L. Results of this analysis before wastewater treatment and after anaerobic treatment are shown in table-2 and figure-2 shows the final comparison analysis of the samples before (B) and after (A) treatment. Variation of COD (A) i.e. COD value after anaerobic treatment of wastewater with that of COD (B) i.e. COD value of raw wastewater (before treatment) is mentioned in equation-2. This equation is the sole outcome after the regression analysis of the obtained COD values.

$$\text{COD(A)} = - 0.141 \text{ COD(B)} + 144.2 \quad \text{-- (2)}$$

**Table-2 COD levels before and after treatment.**

	Before Treatment (mg/l)	After Biological Treatment (mg/l)
Sample-No.	COD-B	COD-A
1.	550	67
2.	550	67.5
3.	555	67.5
4.	552	66
5.	551	65
6.	548	68
7.	556	67
8.	557	67
9.	552	65
10.	556	66
11.	558	64
12.	551	64
13.	556	65
14.	552	67
15.	555	65.5
16.	551	67.5



**Figure-2 Comparative COD analysis of the status of the before and after treatment of 16 wastewater samples.**

### 4.3 TSS

TSS is a measure of the floating particulate content of the wastewater and, in some ways, is an indicator of the clarity of the wastewater. Typical municipal wastewaters will have a TSS in the 180 to 220 mg/L range and effluent

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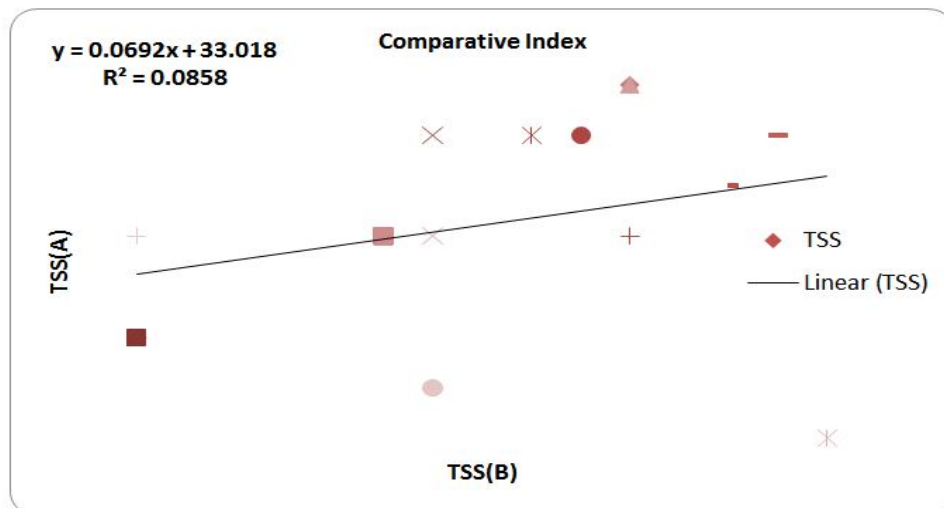
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requirements for TSS for primary plants are in the range of 100 to 130 mg/L TSS. Results of this analysis before wastewater treatment and after anaerobic treatment are shown in table-3 and figure-3 shows the final comparison analysis of the samples before (B) and after (A) treatment. Variation of TSS (A) i.e. TSS value after anaerobic treatment of wastewater with that of TSS (B) i.e. TSS value of raw wastewater (before treatment) is mentioned in equation-3. This equation is the sole outcome after the comparative regression analysis of the obtained TSS values.

$$TSS(A) = 0.069 TSS(B) + 33.01 \quad - (3)$$

**Table-3 TSS levels before and after treatment.**

Sample No.	Before Treatment (mg/l)	After Biological Treatment (mg/l)
	TSS-B	TSS-A
1.	240	49
2.	240	49
3.	245	50
4.	246	51
5.	248	51
6.	249	51
7.	250	50
8.	252	50.5
9.	253	51
10.	250	51.5
11.	245	50
12.	250	51.5
13.	246	50
14.	254	48
15.	246	48.5
16.	240	50



**Figure-3 Comparative TSS analysis of the status of the before and after treatment of 16 wastewater samples.**

#### 4.4 Ammonical N

Ammonia is a wastewater constituent that results from the degradation of proteins. Raw wastewater typically has ammonia concentrations in the 20 to 30 mg/L range, as N, nitrogen. Results of this analysis before wastewater treatment and after anaerobic treatment are shown in table-4.

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**Table-4 Ammonical-N levels before and after treatment.**

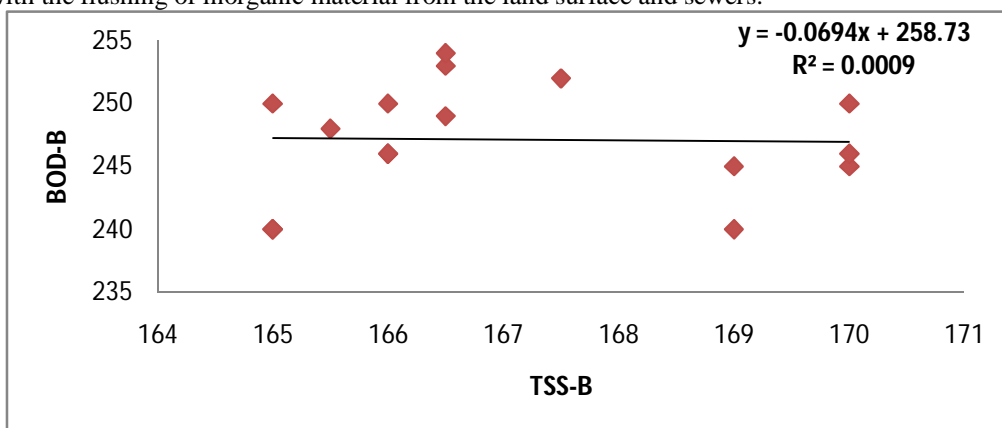
Sample- No.	Before Treatment (mg/l)	After Biological Treatment (mg/l)
	Ammonical-N	Ammoniacal-N
1.	28	25
2.	28	25
3.	26	24
4.	26	24
5.	27	25
6.	26	25
7.	29	26
8.	28	24
9.	28	25
10.	28	25
11.	29	26
12.	28	25
13.	26	24
14.	27.5	25
15.	28	26
16.	26	26

### 4.5 Relationship between TSS and BOD (Influent TSS - BOD and Effluent TSS - BOD)

**4.5.1 Relationship between TSS-B and BOD-B:** The relationship between the TSS-B and BOD-B of all the sixteen samples during the analysis is shown in Figure-4. The data were obtained from the pilot plant tests as shown in Table-1 and 3. BOD and TSS levels for all the sixteen untreated samples were in the range of 165-170 mg/L and ranged from 240 to 254 mg/L. The influent BOD was correlated with the TSS in equation-4.

$$\text{BOD (B)} = -0.0694 \text{ TSS(B)} + 258.73 \quad - (4)$$

Use of the correlation equation estimates BOD-B based on TSS-B. There is absolute disproportionate relation in the BOD-B concentration and TSS-B concentration levels with  $R^2 = 0.0009$ . Large increases in TSS are generally associated with the flushing of inorganic material from the land surface and sewers.



**Figure-4 Relationship between before treatment or influent TSS-B and BOD-B.**

**4.5.2 Relationship between TSS-A and BOD-A:** The relationship between the TSS-A and BOD-A of all the sixteen samples during the analysis is shown in Figure-5. The data were obtained from the pilot plant tests as shown in table-1 and 3. The effluent BOD was correlated with the effluent TSS in equation-5.

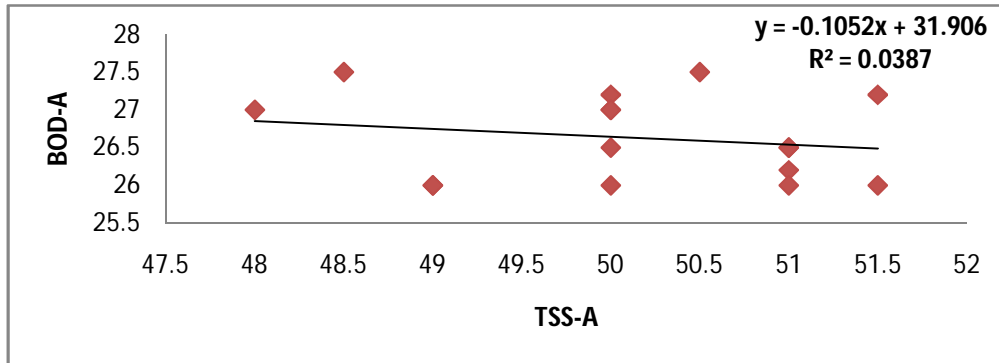
$$\text{BOD (A)} = -0.1052 \text{ TSS(A)} + 31.906 \quad - (5)$$

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Use of the correlation equation estimates BOD-A based on TSS-A. There is very minor relativity between the BOD-A concentration and TSS-A concentration levels with  $R^2 = 0.0387$ . This means that the strength of the relationship between TSS-A and BOD-A was very weak, with less than 4% correlation.



**Figure-5 Relationship between before treatment or influent TSS-A and BOD-A.**

#### 4.6 Correlation between BOD and COD

Since, the COD represents virtually all organic matter, either partially degradable or non-biodegradable and BOD the total oxygen demand, it is necessary to develop relationship between BOD and COD. Since BOD is a measure of the biodegradability of the wastewater, the ratio of BOD-B to COD-B can help further assess the type of biological treatment that is appropriate (Eckenfelder, 1989). Present study possesses a prior BOD-B to COD-B ratio in the range of  $0.302 \pm 0.004$  as mentioned in table-5. This indicates that aerobic biological treatment, like that at the French Creek and Duke Point treatment plants would also have been appropriate. BOD-B and COD-B levels for all the sixteen untreated samples were in the range of 165-170 mg/L and ranged from 548 to 558 mg/L. The influent BOD was correlated with the COD in equation-6. Use of the correlation equation estimates BOD-B based on COD-B. There is again very minor proportionality in the BOD-B and COD-B concentration levels with  $R^2 = 0.0639$ .

$$\text{COD(B)} = 0.4013 \text{ BOD(B)} + 486.07 \quad - (6)$$

**Table-5 BOD-B and COD-B levels before treatment and their ratios.**

BOD-B	COD-B	BOD-B/COD-B
165	550	0.3
165	550	0.3
170	555	0.306
166	552	0.3
165.5	551	0.3
166.5	548	0.304
166	556	0.298
167.5	557	0.3
166.5	552	0.301
165	556	0.296
169	558	0.302
170	551	0.308
166	556	0.298
166.5	552	0.301
170	555	0.306
169	551	0.306



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## V. CONCLUSION

The wastewater treatment performance in the sewage treatment plant at Jalandhar, Punjab indicated a positive efficiency of the system. The overall efficiency after analyzing the 16 samples is in the order of COD > TSS > BOD > ammonical-N. The performance of the treatment system was up to the mark in both the cases. The average percentage removal of BOD in the treatment plants is around 85% illustrating an efficient BOD reduction, for COD it is 89% and for TSS it is around -80%. Unfortunately the ammonical-N average percentage removal lies very low with just around 15% removal efficiency [18] [19]. The overall efficiency of the plant is satisfactory and the mathematical correlations provide a clear indication of the prior basis and the assessment criteria of the effluent product.

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