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RESEARCH ARTICLER

PERFORMANCE EVALUATION OF THE PAGLA SEWAGE TREATMENT PLANT

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ABSTRACT

The Pagla Sewage Treatment Plant (PSTP) was first started in 1968 with 4 facultative lagoons which were further renovated in 1977 to serve about 500,000 citizens in Dhaka city. The present PSTP had been rehabilitated in 1992 by JICA to treat a capacity of 120,000 m3/day. The plant is located 8 km away at the south-east portion of Dhaka city and about 1 km north of the Buriganga. The plant has been designed considering influent BOD5 of 200 mg/l and effluent BOD5 of 50 mg/l which indicates that PSTP is designed to treat domestic wastewater. The laboratory test results of Pagla Sewage Treatment Plant were collected from the office situated within the premise of the plant. The PSTP is a multi stage treatment plant in which BOD5 and SS is measured at inlet, outlet at primary sedimentation tank and outlet of lagoons. Generally, in PSTP SS data is recorded in every alternate day while BOD5 is generally recorded twice a week. From all the available data it is obtained that average influent BOD5 is 398 mg/l and effluent BOD5 is 79.31 mg/l which is greater than design value(influent 200 mg/l and effluent 50 mg/l). Also SS has the same efficiency as that of BOD5. Also yearly variations for BOD5 have been obtained. From 1999 and onwards high concentration of BOD5 and SS indicates strong evidence of industrial wastes entering PSTP. Seasonal variation in concentration of BOD5 and SS is also pronounced. In dry season high concentration is observed and in wet season relatively low concentration is obtained. From the obtained data correlation between BOD5 and SS can be obtained well at inlet. But correlation between BOD5 and SS is rather poor at outlet. Also correlation between different months shows good relationship both for BOD5 and SS.

For the improvement of the performance of Pagla Sewage Treatment Plant immediate cleaning of the lagoon is recommended. It is also necessary to record the data in user friendly interface in computer format and also improvement of laboratory facilities for constant effective supervision. Moreover, the reasons for high BOD5 concentration should be identified by closely monitoring the influent characteristics. In case of industrial discharge mixing into city sewerage network it must comply with Environment Quality Standards. Finally, considering the performance of PSTP the option for constructing more sewage treatment plant should be seriously in contention.

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INTRODUCTION

The first built pipe borne sewerage system for Dhaka city dates back to 1923 by the then British Government. The scenarios have been changing after 1947 when the Indian sub-continent was divided and Dhaka become regional centre. Prior to 1947, the sewerage system of Dhaka consisted of approximately 50 km of sewer lines, a lift pump station at Narinda. After 1947, the Directorate of Public Health Engineering (DPHE) of the then Government of East Pakistan constructed 60 km of sewer lines and 6 pump stations at Maghbazar, P & T, Faridabad, Medical College, Azimpur, Nilkhet and Nawabganj and the discharge of these pump stations were collected to sump well of Narinda pump station. On 14th November, 1963, DWASA was created as an autonomous body and all the above mentioned installations and the network are transferred to DWASA. At present Dhaka city has about 531 km sewer lines and 20-sewage lift stations in the sewerage system. The first conventional sewage treatment plant with 4 facultative lagoons was built at Pagla in 1968. In 1977, the Pagla Sewage Treatment Plant was renovated to serve about 500,000 citizens of Dhaka city. The present Pagla sewage treatment plant has been rehabilitated in 1992 to treat a capacity of 120,000 m^3/day sewage. The plant has been designed considering influent BOD_5 as 200 mg/l and effluent BOD_5 of 50 mg/l. This shows that Pagla sewage treatment plant was designed to treat only domestic wastewater.

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Pagla Sewage Treatment Plant: In 1968 with 4 ponds, Pagla Sewage Treatment Plant was constructed by DWASA for the Dhaka city. The present Pagla Sewage Treatment Plant was built to serve 500000 citizens in the year 1977 (JICA, 1988).The plant has been rehabilitated and expanded in 1992 under JICA funded Urgent Sewerage Construction & Rehabilitation Project. The present plant has been designed to treat hourly maximum flow of 120000 m^3/day, considering influent BOD_5 as 200 mg/l and effluent BOD_5 as 50 mg/l. There are different studies of BOD_5 have been conducted by different groups. BOD_5 was also monitored in the laboratory located within the plant site. Results of BOD_5 among the studies differ abnormally. Thus, it is necessary to find out the actual BOD_5 of influent and effluent of the plant to evaluate the performance of Pagla Sewage Treatment Plant of Dhaka city. Pagla Sewage Treatment Plant has been reconstructed under the urgent sewerage rehabilitation project of JICA in 1992. The total area of the treatment plant (including DWASA staff quarter) is 110.5 ha of which 87.7 ha is the present plant area. Present ground level is + 1.8 m to + 6.9 m whereas design ground level is + 6.7 m to + 6.9 m. The Tables 1.1 and 1.2 show the design and existing flow rates and the outline of major facilities of Pagla STP. The main units of the treatment plant are pretreatment, primary sedimentation tanks, facultative lagoons and sludge stabilization lagoons. The recipient is Buriganga river which has a maximum water level at + 6.7 m.

Table 1. Design Flow Rate and Existing Flow Rate of PSTP

Flow	Full scale Design (m^3/day)	Existing Facility (m^3/day)
Daily Average	146,000	96,000
Daily Maximum	183,000	120,000
Hourly Maximum	232,000	120,000

Literature Review

The collection and conveyance of wastewater (sewage) from the various sources at the point of generation is the first step in the effective management of a community's wastewater. The pipes that collect and transport the wastewater away from its point of generation are called sewers, and the network of sewer pipes in a community is known as sewerage system. [1] There are three types of collection sewerage systems have been developed: (i) Sanitary, (ii) Storm-sewers, and (iii) Combined sewers. Sanitary sewers, which are often called separate sewers/conventional sewer, originally were intended solely for the collection of wastewater from residential district as a mean of improving the general sanitation of the community. [2] Sewage is a liability to the community. Therefore, it must be collected and transported from the point of production to the treatment plant or final disposal as quickly as possible to prevent development of septic conditions so that it can not endanger public health. [3] The Milwaukee, Wisconsin epidemic of domestic water supply waterborne disease caused by *Cryptosporidium* in the spring of 1993 in which over 400,000 people became ill and over 80 people died has stimulated renewed attention to the potential significance of pathogenic organisms in domestic water supplies. It has been recently reviewed that the significance of domestic water supply waterborne pathogens as a cause of disease in the US population. [4] It has been recently estimated that the lifetime risk of death for the US population from waterborne enterovirus pathogens is 1 in 20. [5] Therefore, the lifetime risk of disease and death from waterborne pathogens in domestic water supplies is far greater than the risks associated with the chemical contaminants (Priority Pollutants), individually or all of them combined, that are the focus of current regulatory attention. In general, from about 1900 to the early 1970s treatment objectives were concerned with (i) the removal of suspended and floatable materials, (ii) the treatment of biodegradable organics, and (iii) the elimination of pathogenic organisms. [6] But now, wastewater treatment objective is based primarily on aesthetic and environmental concerns. The activated sludge process was involved the production of an activated mass of micro-organisms capable of stabilizing of a waste aerobically. Many versions of the original processes are in use today, but fundamentally they are all similar. [2]

A major effort has been undertaken to improve the quality of the surface waters. Since 1980, because of increased scientific knowledge and an expanded information base, wastewater treatment has begun to focus on the health concerns related to toxic and potentially toxic chemicals released to the environment. [2] The first step of sewage treatment is usually the removal of large floating objects and heavy mineral particles. Coarse solids are removed by a series of closely spaced mild steel bars placed across the flow. For large flows mechanically raked screens are preferred since they can be cleaned more frequently and are considerably smaller than the corresponding hand raked screen. [6] Grit is the heavy inorganic fraction of sewage solids. It includes road grit, sand, eggshells, ashes, charcoal, glass and pieces of metal etc. There are two basic types of grit removal plant; constant velocity grit channels and the various proprietary tanks or taps available commercially. [6] A comminutor is a self-cleansings shredding machine. Comminutors avoid the problems with the handling and disposal of screenings. [6] The activated sludge process involved the production of an activated mass of micro-organisms capable of stabilizing of a waste aerobically. Many versions of the original processes are in use today, but fundamentally they are all similar. [2] The concept of a trickling filter grew from the use of contact filters, which were watertight basins filled with broken stones. In operation, the contact bed was filled with wastewater from the top, and the wastewater was allowed to contact the media for a short time. The bed was then drained and allowed to rest before the cycle was repeated. [2] A trickling filter is a packed bed of media covered with slime growth over which wastewater is passed. As the wastewater passes through the filter, organic matter present in the wastewater is removed by the biological film. [7] This process is similar to the conventional Activated Sludge Process except that Primary Sedimentation Tank does not use here. [8] In this process, sludge wasting is minimized. This results in low growth rates, low sludge yields, and relatively high oxygen requirements by comparison with the conventional Activated Sludge Processes. [7]

Aerated lagoons are activated sludge units operated without sludge return. They are developed from waste stabilization ponds in temperature climates where mechanical aeration was used to supplement the algal oxygen supply in winter. Aerated lagoons are now usually designed as completely mixed non-return activated sludge unit.[6] The rotating biological contractor consists of large-diameter plastic media mounted on a horizontal shaft in a tank. The contractor is slowly rotated with approximately 40% of the surface area submerged. A 1-4 mm layer of slime biomass is developed on the media. Shearing forces cause excessive biomass to be stripped from the media in a manner similar to a trickling filter. [7] In the US and Canada, 70% of RBC systems installed are used for

Table 1.2. Outline of Major Facilities

Facility	Dimension	No.of existing facilities	No. of final facilities	Capacity
Inflow	Brick Arch Sewer Dia Ø 54"(Equ) Slope 0.45% Sewer pipe Invert Level +0.762 Sewer dia Ø 1800 Slope 0.45% Invert Level +0.485	1	1 1	
Lift Pump	Screw Pump Ø 1600 x 41m^3/min x 3.8 m x 45 KW	3	5	
Grit Chamber	Horizontal Flow Type W 3.3 m x L 10.2 m x D 1.42 m	2	2	Surface Load : 3600 m/day
Primary Sedimentation Tank	Centrifloc Sludge Scraper Ø 33 m x D 3 m	4	6	Detention : 2.02 hr Overflow rate : 35.7 m/day
Facultative Lagoon	Embanked Rectangular Pond Effective Depth : 2.0 m	42 ha	64 ha	Retention Day : 7 BOD Area Load : 343 kg BOD/ha x day
Discharge Pump	Horizontal Centrifugal pump Ø 250 mm x 4.55 m^3/min x 10.7 m Ø 250 mm x 11.36 m^3/min x 10.7 m Ø 400 mm x 31.82 m^3/min x 10.7 m	 2 2 3	 2 2 3	
Disinfection Equip.	Liquid Chlorine	1	1	Max'm Dosing rate : 3 mg/l
Sludge Lagoon	Embanked Rectangular Pond	4	4	Solid Load 75 kg/m^3/yr
Discharge Pipe	Brick Arch	2	2	Gravity Flow only

carbonaceous removal only, 25% for combined carbonaceous BOD removal and nitrification, and 5% for nitrification of secondary effluent. [2] Waste stabilization ponds are large shallow basins enclosed by earthen embankments in which raw sewage is treated by entirely natural processes involving both algae and bacteria. They are without doubt the most important method of sewage treatment in hot climates where sufficient land is normally available. [6] Ponds systems can be classified as (i) Aerobic, (ii) facultative, (iii) maturation, and (iv) anaerobic with respect to the presence of oxygen. [2] Maturation ponds are used as a second stage to facultative ponds. Their main function is the destruction of pathogens. Maturation ponds are wholly aerobic and are able to maintain aerobic conditions at depths up to 3 m. But normally depth is taken as that of facultative ponds (1-1.5 m), since the destruction of viruses is better in shallow ponds than in deep ones. [6]

In the UASB process the following units are normally used for wastewater treatment [9]

- Flow restriction and measurement
- Coarse and fine screens
- Grit chamber
- UASB reactor
- Facultative pond

The constituents removed in wastewater treatment plants include screenings, grit, scum, and sludge. The sludge resulting from wastewater treatment operations and processes is usually in the form of a liquid or semisolid liquid that typically contains from 0.25-12% solids by weight. Digestion, composting, incineration, wet-air oxidation, and vertical tube reactors are used primarily to treat or stabilize the organic material in the sludge. Characteristics of sludge that affect its suitability for land application and beneficial use include organic content, nutrients, pathogens, metals, and toxic organics. The term heavy metal is used to denote several of the trace elements present in sludge. For land application of sludge, concentrations of heavy metals may limit the sludge application rate and the useful life of the application site. [2]

Oxygen Depleting Parameters

Following are the oxygen depleting parameters:

- Biochemical Oxygen Demand (BOD) which is also divided in to (a) Nitrogenous Biochemical Oxygen Demand (NBOD), and (b) Carbonaceous Biochemical Oxygen Demand (CBOD).
- Chemical Oxygen Demand (COD).

The most widely used parameter of organic pollution applied to both wastewater and surface water is the 5-day BOD (BOD_5).The BOD_5 by the definition is the quantity of oxygen required for the stabilization of the oxidizable organic matter present after 5 days of incubation at 20º c. [7] Non carbonaceous matter, such as ammonia, is produced during hydrolysis of proteins. The interference caused by the presence of nitrifying bacteria can be eliminated by pretreatment of the sample or by the use of inhibitory agents. The CBOD test is now being used as substitute for the BOD test in discharge permits, especially where nitrification is known to occur. [2]
The COD test measures the total organic carbon with the exception of certain aromatics, which are not completely oxidized in the reaction. The COD is an oxidation-reduction reaction, so other reduced substances, such as sulfides, sulfites, and ferrous iron, will also be oxidized. [7]

MATERIALS AND METHODS

In this study the performance of Pagla Sewage Treatment Plant of Dhaka City will be compared with expected results.

Methodology Used in the Study

Criteria for Performance evaluation: *Pagla Sewage Treatment Plant*

Parameter	Influent (mg/l)	Removal Ratio(%) for PST	Effluent from PST (mg/l)	Facultative Lagoon Removal Ratio (%)	Facultative lagoon Effluent (mg/l)	Total Removal Ratio(%)
BOD_5	200	40	120	59	50	75

1) Design Flow = 120,000 m^3/day
2) Design Quality
3) Detention Period
   a. Primary Sedimentation Tank = 2.02 hr
   b. Facultative Lagoon (FL) = 7 days
4) Design Water Level of F.L. = 2.7 m PWD
5) Design effective depth of Sewage in FL = 2.0 m.

Field Investigation: The Pagla Sewage Treatment Plant which is located to the extreme south of the city has been visited under the careful monitoring and supervision of the thesis supervisor to find out the overall physical condition including pumping station, lagoons, laboratory facilities, etc. in February, 2006.

Procedure Followed

- Taken 125 ml sample + 125 ml dilution water in 250 ml BOD bottle
- The initial DO has been determined (by azide modification method)
- Incubated for 5 days at 20°c in an incubator and the final DO has been determined.

Calculation

BOD_5 at 20°c (mg/l) = Doi – Dof

Where
Doi = initial DO of sample (mg/l)
Dof = Final DO of sample (mg/l)

DATA ANALYSIS & RESULTS DISCUSSION

Treatment Performance

It is estimated that about 150,000 m^3/day (ISS, 1998a) wastewater has been generated within the Dhaka City conventional sewerage system. As most of the trunk sewers were constructed in the early 1960's in a low, open area, not along the road, and presently portion are broken due to differential settlement of the ground and in some cases may be intentionally. In overall, about 70,000 m^3/day are collected near Saidabad trunk main and discharging to the trunk main while about 40,000 m^3/day are arriving to Pagla STP. Accordingly, the missing volume can be assumed to be leakage from the broken part of the sewer mains. The performance of Pagla Sewage Treatment Plant can be assessed only through the comparison to the design value and the value found through different studies of the same parameters.

The Design Sewage Flow Rate is = 120,000 m^3/day.

A laboratory room with necessary facilities exists in the administrative building of the Pagla STP to analyze the different parameters to assess the effluent quality. Samples are taken either once a week (for BOD) or every alternate days (for SS) at :

Distribution Chamber
Outlet of Primary Sedimentation Tank
Outlet of 'A' and 'B' lagoons.

A microbiologist analyses the SS and BOD_5 for each sample. The BOD_5 meter was damaged in October, 1995. Then only SS was measured. Table 4.1 shows the existing equipment in the laboratory at the Pagla STP.

Table 3.1. Existing Equipment in the Pagla Laboratory

Item	Type and Manufacturer	Quantity	Present Status
Digital DO / Meter	Bionic Industry Co., Ltd, DO-715K	1 unit	Functional
pH meter	Horiba	1 unit	Functional
Drying Oven	Yamato	1 unit	Functional
Incubator	Sanyo	1 unit	Functional
Vacuum Pump	Yamato	1 unit	Functional
Glass Ware	Yamato	1 set	

3.2 RESULT DISCUSSION

3.2.1. Average Removal of BOD_5 and SS: By considering all the recorded data for all the year the following tables are obtained:

Table 3.2. Average Removal of BOD_5

Inlet (mg/l)	Pst (mg/l)	Overall Removal(%)	Outlet (mg/l)	Overall Removal(%)
398	152	54.97	70	79.31

Table 3.3. Average Removal of SS

Inlet (mg/l)	Outlet Pst (mg/l)	Removal% Of pst	Mean removal A &b (%)	Mean removal A&b (mg/l)
264	105	58.21	80.09	45

From the above two tables it can be stated that the overall efficiency for BOD_5 and SS removal is almost same. It indicates the BOD and SS removal procedure are compatible to each other.

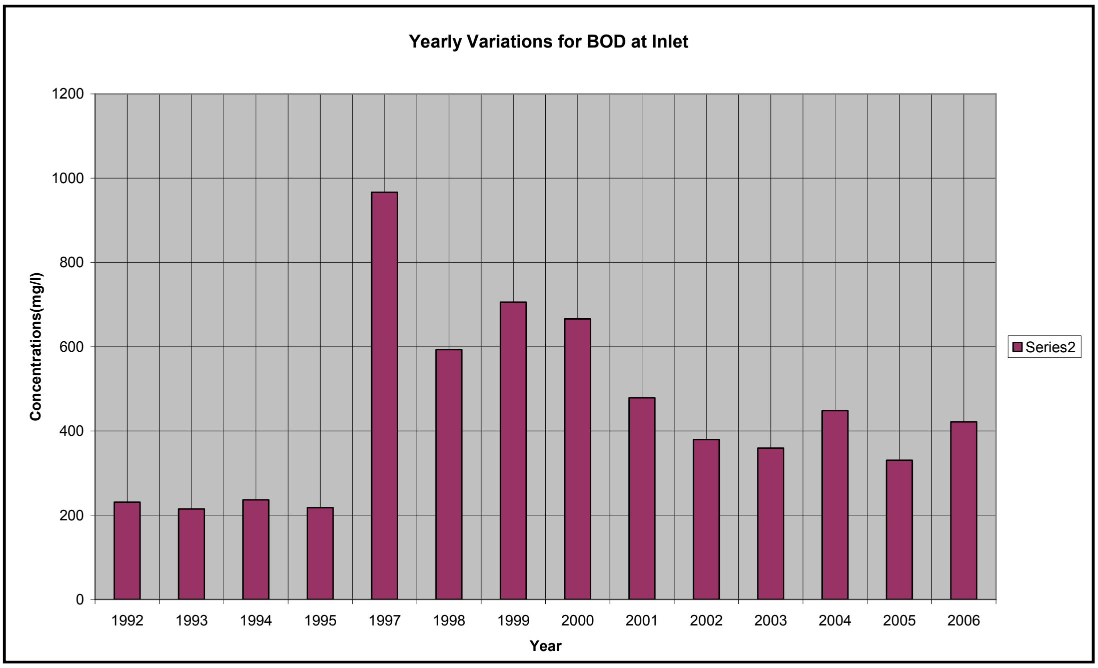
3.2.2. Yearly Variation

A. Yearly variation for BOD at Inlet, Outlet of PST and at the final Outlet is shown below:

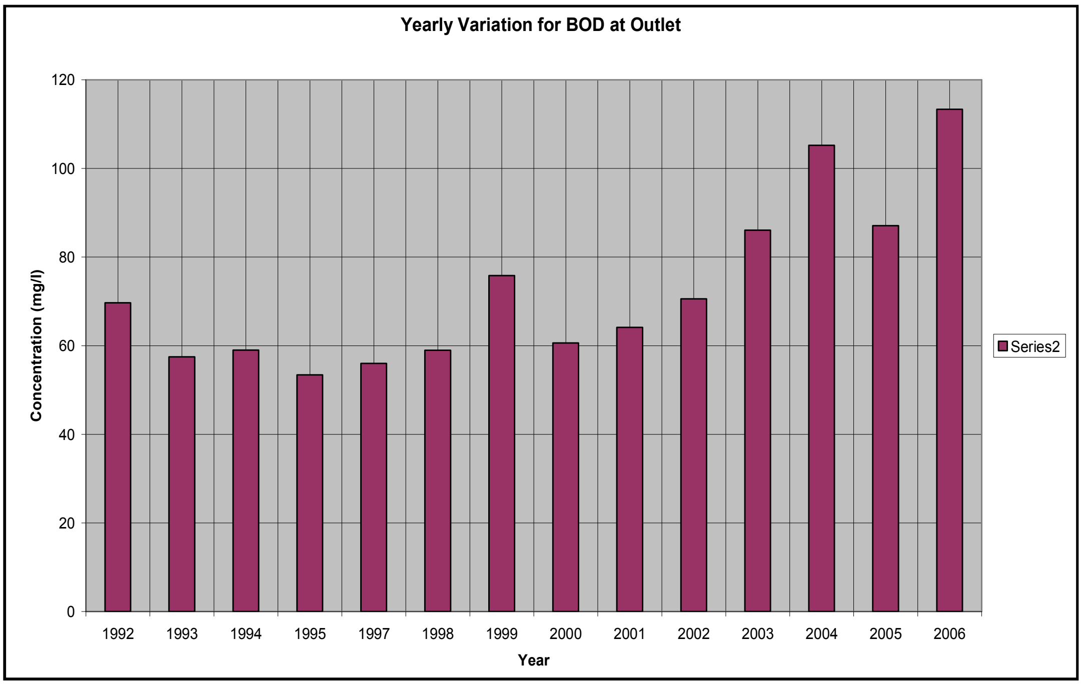
Table 3.4. Yearly Variation of BOD_5

Year	Inlet (mg/l)	Pst (mg/l)	Overall Removal (%)	Outlet of Lagoon (mg/l)	Overall removal(%) of lagoon
1992	231	132	42.46	70	69.59
1993	215	120	43.84	57	73.07
1994	236	128	45.88	59	74.90
1995	218	120	44.61	53	75.40
1997	967	-	-	56	94.16
1998	593	-	-	59	89.23
1999	706	131	80.39	76	88.62
2000	666	213	66.82	61	90.51
2001	478	196	55.17	64	85.27
2002	380	181	51.86	71	81.34
2003	359	149	58.68	86	75.98
2004	448	169	62.40	105	76.64
2005	331	130	61.09	87	73.96
2006	422	169	60.25	113	73.27

From the plot 3.1 and above it is evident that BOD at inlet has an increasing trend towards the future years. This might either because of increasing pollution of water by the growing population or effluent of industrial waste is mixed in water.



Plot 3.1. Yearly Variation of BOD_5 at Inlet



Plot 3.2. Yearly variation of BOD_5 at Outlet

Table 3.5. Yearly Variation of SS

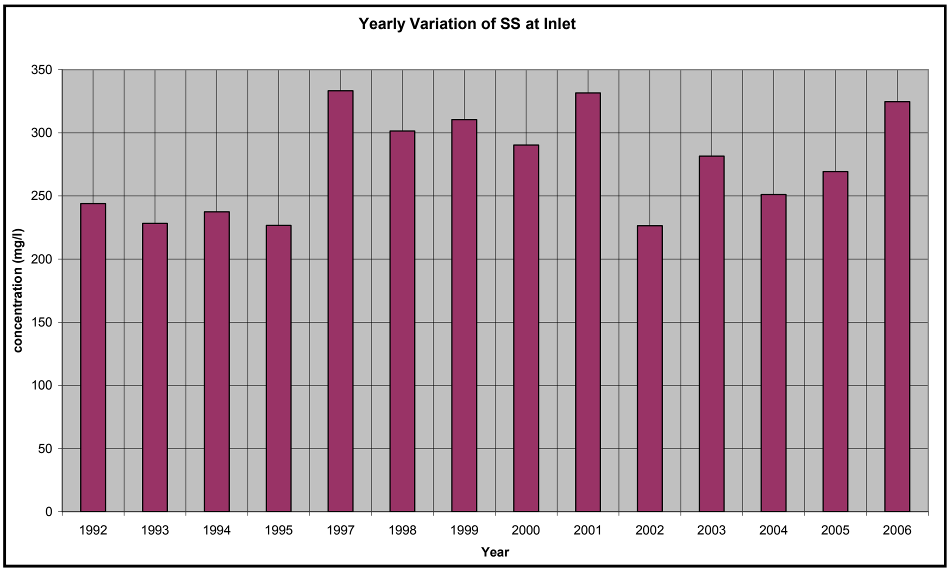
Year	Inlet(mg/l)	Outlet pst (mg/l)	Removal% of pst	Mean Removal Lagoon Outlet(%)	Mean Removal Lagoon Outlet (mg/l)
1992	244	112	52	77	54
1993	228	112	51	79	49
1994	237	114	52	77	54
1995	227	98	57	75	57
1997	333	103	66	81	60
1998	301	92	66	82	49
1999	311	89	69	84	45
2000	290	104	61	82	45
2001	332	100	65	84	47
2002	226	99	61	81	40
2003	282	101	63	84	43
2004	251	114	54	78	52
2005	269	111	58	81	50
2006	325	127	60	84	49

Specially 1997 the inlet BOD_5 is at its highest level closing to 1000 mg/l which very much represents strong component of industrial wastewater. From this plot it can be seen that outlet BOD concentration is also increasing over the years. This means the plant can not remove the huge BOD at inlet sufficiently and there is deterioration of water quality at Buriganga as increasing concentration in BOD which affects the water quality in the river negatively.

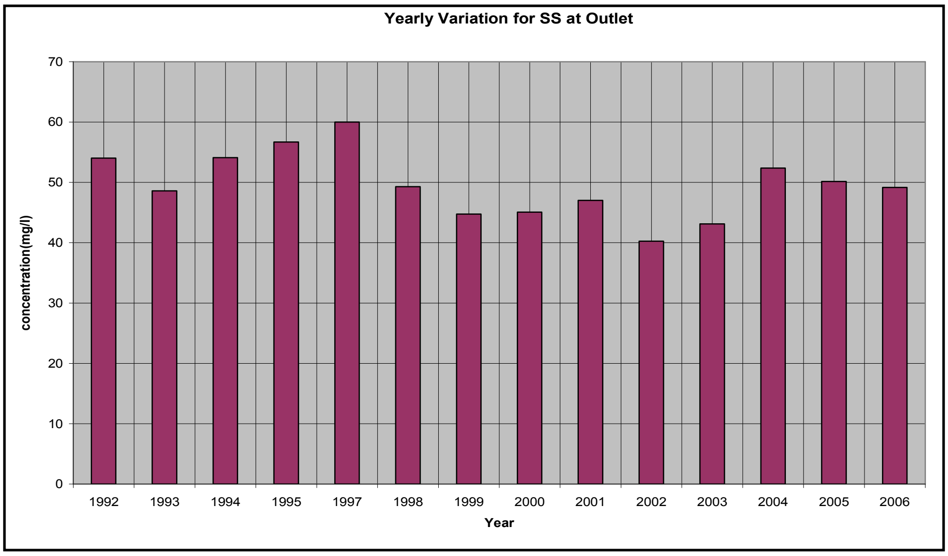
Yearly variation for SS is shown below

From the above plot and table it can be seen that SS is also an increasing trend like BOD over the years. The range may vary from around 240-330 mg/l. This may be incorporated with garments fibres, knitting particles and other industrial dust particles.

November-May i.e. in dry season but the concentration of BOD_5 is low fro June-October i.e. in the rainy season. This is because in rainy season wastewater is diluted with the runoff resulting from heavy rainfall and thereby reducing the concentration of BOD_5. The concentration is the lowest in July, August, September when highest rainfall occurs. The concentration varies from 470 mg/l to 330 mg/l. From the above plot it is evident that in rainy season the outlet has the lower concentration of BOD than in dry season. So in rainy season, obviously, the effluent water quality of the plant improves considerably. The highest concentration occurs in May and the lowest occurs in the month of July which is compatible to assumed condition. The range varies from 76-60 mg/l. The above plot is similar to that of BOD_5 which shows higher concentration in dry season and lower concentration in wet or rainy season.



Plot 3.3. Yearly Variation of SS at Inlet



Plot 3.4. Yearly Variation for SS at Outlet

From the above plot it is evident is SS removal is in reasonable limit as SS concentration is not increasing gradually. So SS removal efficiency may be termed as fair.

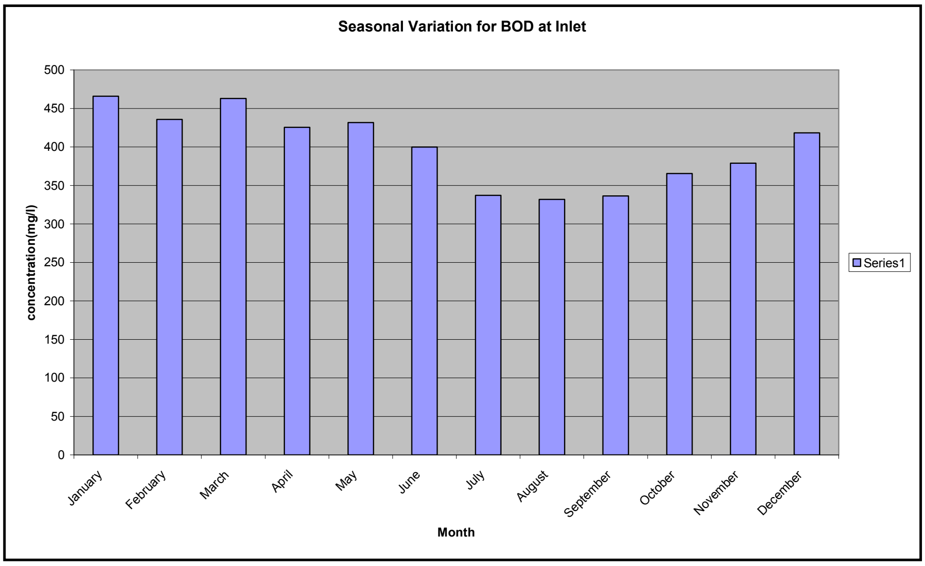
3.2.3. Seasonal Variation

Seasonal variation for BOD_5 is shown below: From the above plot it can be seen that BOD_5 has high concentration from

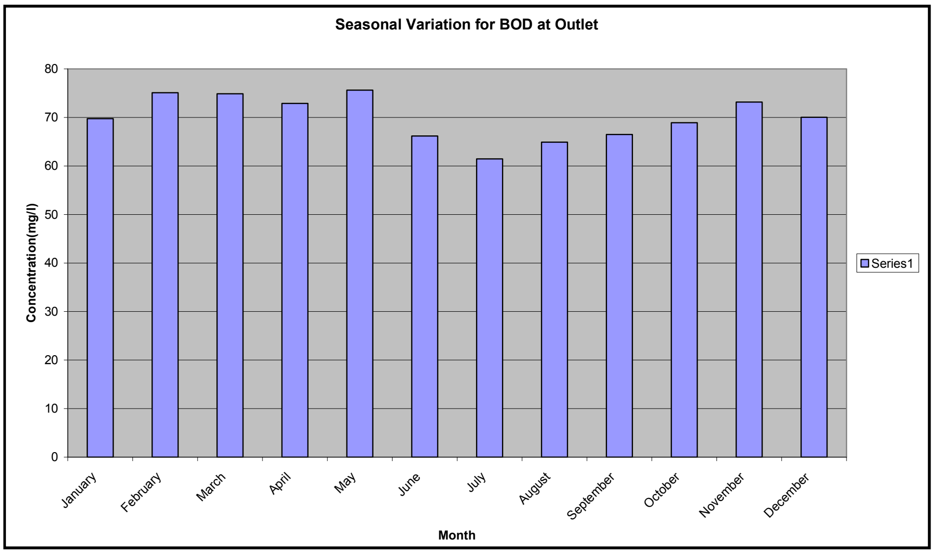
Lowest concentration occurs in the month of August and the highest occurs in the month of January. The range vary from 220 mg/l to 330 mg/l. The above plot is compatible to SS inlet and BOD at outlet. The lowest concentration occurs in the month of October and the highest concentration occurs in the month of March which is reasonable to the seasonal characterstics. The concentration varies from 44 mg/l to 56 mg/l.

Table 3.6. Seasonal Variation for BOD_5

Month	Inlet (mg/l)	Pst (mg/l)	Overall Removal (%)	Outlet (mg/l)	Overall Removal (%)
January	466	168	55.10	70	81.28
February	436	162	55.18	75	79.57
March	463	158	56.20	75	79.03
April	425	166	53.58	73	79.64
May	432	173	54.16	76	80.14
June	400	156	54.69	66	79.81
July	337	147	52.59	61	79.35
August	332	132	54.20	65	77.45
September	336	129	57.78	67	78.20
October	365	125	59.27	69	78.48
November	379	152	54.16	73	78.74
December	418	154	52.31	70	80.26



Plot 3.5. Seasonal Variation for BOD_5 at Inlet



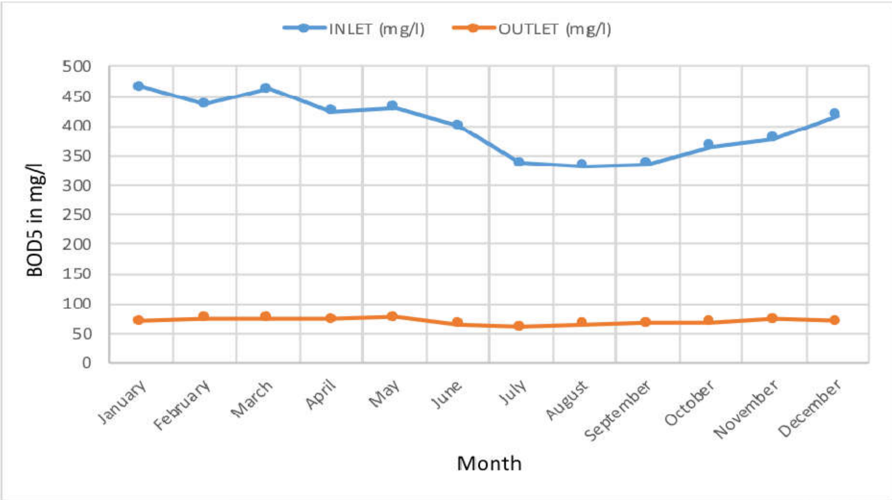
Plot 3.6. Seasonal Variation of BOD_5 at Outlet

3.3 Correlation

3.3.1 General

Correlation is done to relate one parameter with other. Then by knowing one parameter other parameter can be obtained from the tabulated result. This method can be very suitably used Pagla Sewage Treatment Plant. By knowing SS value BOD concentration can be obtained, also by considering inlet value concentration at outlet and PST can be obtained. Furthermore, by correlation matrix relation between different months can be found.

If the correlation co-efficient is 0.4 and onwards the correlation can be considered fair and the two parameters are well correlated. For the value of correlation coefficient of 0.8 and greater the correlation is termed excellent.

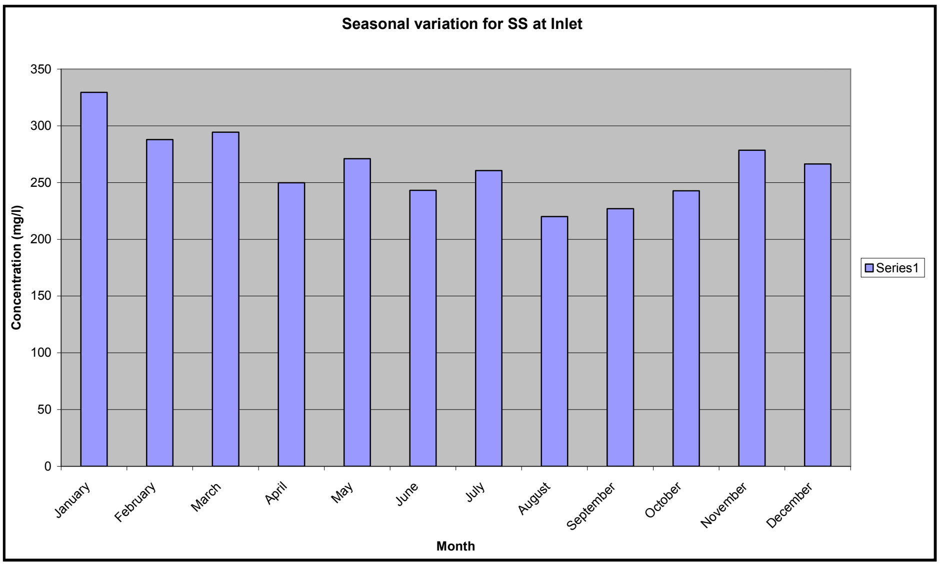


Plot 3.7. Seasonal Variation of BOD_5 (Inlet vs Outlet)

Seasonal Variation for SS is shown in the following

Table 3.7. Seasonal Variation for SS

Month	Inlet (mg/l)	Outlet PST (mg/l)	Removal% OF PST	Mean Removal A &B (%)	Mean Removal A&B (mg/l)
January	330	127	60.06	82.89	50
February	288	116	57.57	80.64	52
March	294	110	57.87	79.52	56
April	250	101	58.78	79.34	51
May	271	102	60.07	79.72	52
June	243	98	58.56	79.29	48
July	261	102	60.09	81.47	46
August	220	96	55.48	78.14	47
September	227	94	56.74	78.43	47
October	243	103	56.45	80.65	44
November	279	111	58.12	81.55	48
December	266	105	57.94	79.13	52



Plot 3.8. Seasonal Variation for SS at Inlet

3.3.1.1 Correlation between BOD_5 and SS

At inlet by using correl function in MS Excel the correlation equation between BOD and SS is obtained as follows:

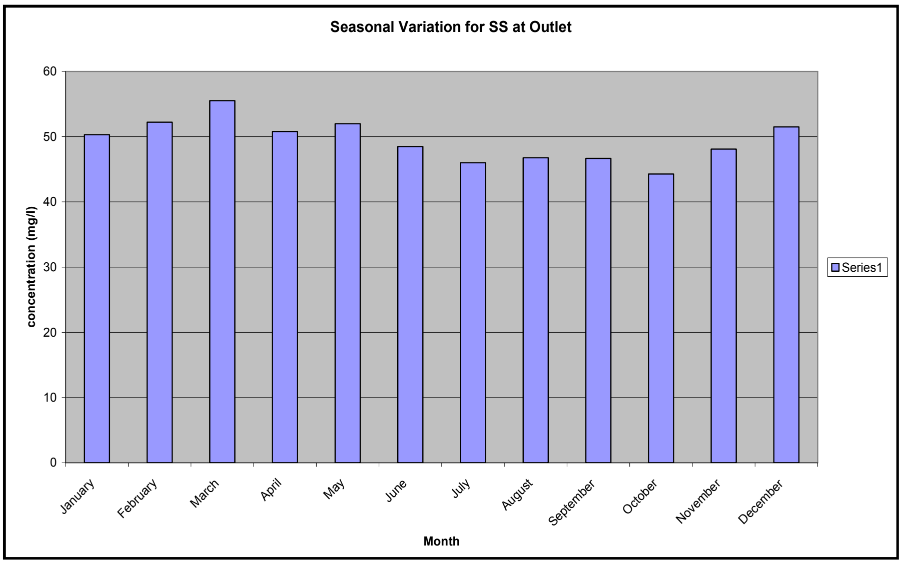
$BOD_5 = 0.7887\ SS + 175.34$

The co-efficient of correlation, R = 0.37.

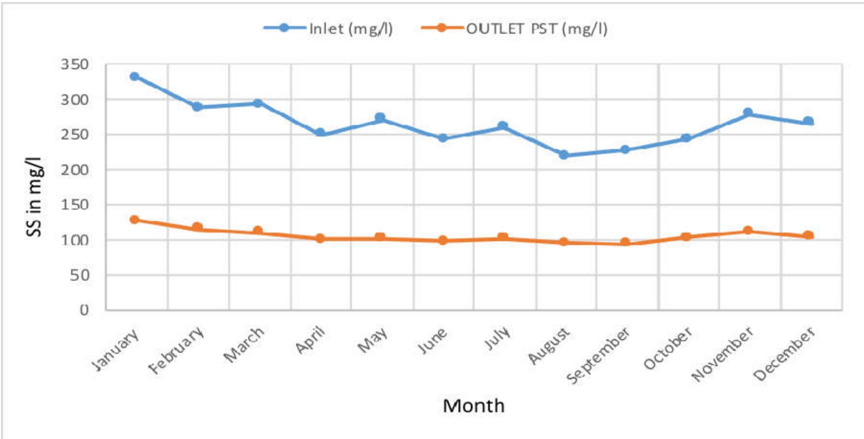
So the correlation is more or less fair as the coefficient is close to 0.4 and by knowing SS concentration the concentration of **BOD_5** can be fairly obtained.

Similarly, at outlet equation between BOD and SS can be obtained as follows:

$BOD_5 = 0.0281\ SS + 68.676$



Plot 3.9. Seasonal Variation for SS at Outlet



Plot 3.10. Seasonal Variation for SS at Inlet vs Outlet

The correlation coefficient, R = 0.022

So the correlation is poor and at outlet by considering SS will not give the value of concentration of BOD_5.

3.3.1.2 Correlation of Inlet, Primary Sedimentation Tank (PST) and Outlet for BOD

The correlation equation between inlet and PST for BOD can be stated as follows:

BOD_5 at PST = 0.1465 x + 95.924

And x = concentration of BOD_5 at Inlet.
The correlation coefficient, R = 0.59.
So the correlation is fair between inlet and PST.

The correlation equation between inlet and outlet for BOD is given below:

BOD_5 at Outlet = 0.0319 x + 57.143

And x = concentration of BOD_5 at Inlet
The correlation co-efficient, R = 0.3.

So Inlet and Outlet BOD_5 concentration is not well correlated.

3.3.1.3 Correlation of Inlet, Primary Sedimentation Tank (PST) and Outlet for SS

The correlation between Inlet and PST for SS can be given by the following equation:

SS at PST= 0.1326 x + 70.204

And x = concentration of SS at Inlet
The correlation coefficient, R = 0.42
Hence the correlation between Inlet and PST concentration of SS is fair.

The correlation equation between Inlet and Outlet is stated below:

SS at Outlet = 0.0466 x + 36.957

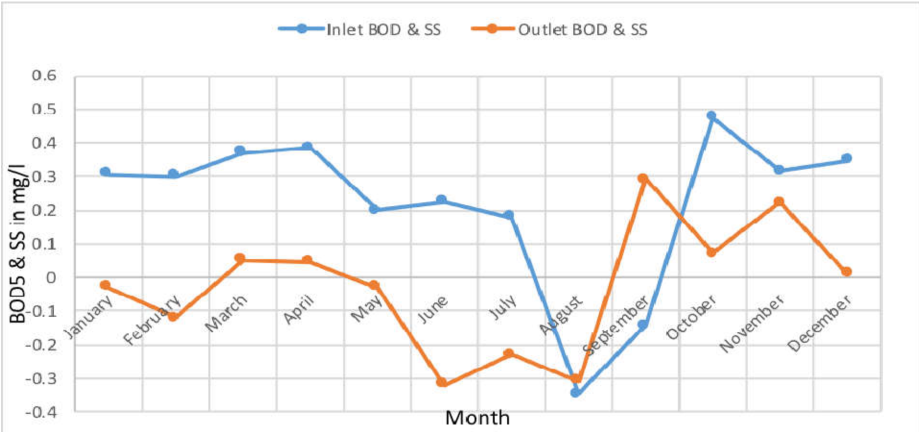
And x = concentration of SS at Inlet
And the correlation co-efficient, R = 0.38
So the correlation for SS value between Inlet and Outlet is more or less fair.

3.3.2 Monthly Correlation between BOD_5 & SS at Inlet and Outlet

This correlation is given by the Table 3.8:

Table 3.8. Correlation Co-efficient between BOD_5 and SS on Monthly basis

	Inlet BOD & SS	Outlet BOD & SS
January	0.3058	-0.0286
February	0.3022	-0.1192
March	0.3705	0.0528
April	0.3847	0.0464
May	0.2003	-0.0306
June	0.2245	-0.3176
July	0.1784	-0.2297
August	-0.3443	-0.3083
September	-0.1421	0.2911
October	0.4749	0.0733
November	0.3158	0.2228
December	0.3472	0.0117



Plot 3.11. Inlet BOD5 & SS vs Outlet BOD5 & SS

Table 3.9. Correlation matrix for BOD_5 at Inlet

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
January	1.00	0.92	0.92	0.76	0.43	0.70	0.64	0.63	0.59	0.85	0.82	0.25
February	0.92	1.00	0.83	0.69	0.45	0.54	0.51	0.43	0.40	0.79	0.82	0.27
March	0.92	0.83	1.00	0.87	0.63	0.79	0.75	0.69	0.72	0.86	0.81	0.16
April	0.76	0.69	0.87	1.00	0.87	0.90	0.88	0.80	0.84	0.91	0.89	0.19
May	0.43	0.45	0.63	0.87	1.00	0.64	0.69	0.50	0.63	0.65	0.70	0.05
June	0.70	0.54	0.79	0.90	0.64	1.00	0.94	0.98	0.95	0.91	0.83	0.23
July	0.64	0.51	0.75	0.88	0.69	0.94	1.00	0.93	0.97	0.89	0.87	0.12
August	0.63	0.43	0.69	0.80	0.50	0.98	0.93	1.00	0.95	0.84	0.75	0.20
September	0.59	0.40	0.72	0.84	0.63	0.95	0.97	0.95	1.00	0.80	0.76	0.08
October	0.85	0.79	0.86	0.91	0.65	0.91	0.89	0.84	0.80	1.00	0.96	0.29
November	0.82	0.82	0.81	0.89	0.70	0.83	0.87	0.75	0.76	0.96	1.00	0.30
December	0.25	0.27	0.16	0.19	0.05	0.23	0.12	0.20	0.08	0.29	0.30	1.00

Table 3.10. Correlation Matrix for BOD at Outlet

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
January	1.00	0.59	0.62	0.64	0.47	0.39	0.49	0.29	0.55	0.49	0.52	0.83
February	0.59	1.00	0.76	0.77	0.83	0.49	0.56	0.20	0.28	0.84	0.44	0.77
March	0.62	0.76	1.00	0.91	0.94	0.48	0.49	0.10	0.21	0.85	0.28	0.52
April	0.64	0.77	0.91	1.00	0.90	0.58	0.66	0.35	0.51	0.76	0.51	0.60
May	0.47	0.83	0.94	0.90	1.00	0.40	0.42	0.03	0.13	0.89	0.39	0.54
June	0.39	0.49	0.48	0.58	0.40	1.00	0.88	0.81	0.62	0.54	0.39	0.50
July	0.49	0.56	0.49	0.66	0.42	0.88	1.00	0.86	0.81	0.52	0.51	0.55
August	0.29	0.20	0.10	0.35	0.03	0.81	0.86	1.00	0.88	0.10	0.43	0.36
September	0.55	0.28	0.21	0.51	0.13	0.62	0.81	0.88	1.00	0.09	0.58	0.50
October	0.49	0.84	0.85	0.76	0.89	0.54	0.52	0.10	0.09	1.00	0.39	0.66
November	0.52	0.44	0.28	0.51	0.39	0.39	0.51	0.43	0.58	0.39	1.00	0.71
December	0.83	0.77	0.52	0.60	0.54	0.50	0.55	0.36	0.50	0.66	0.71	1.00

From the above table it is evident that at inlet BOD and SS is fairly correlated and the best correlation occurs in the month of October when correlation coefficient is 0.47. While at outlet BOD_5 and SS are poorly correlated as most of the correlation coefficient value is less than 0.3.

3.3.3 Correlation Matrix for BOD_5

This is given in Table 3.9 and 3.10. From the above table it is evident that at inlet the values of all the months except December is well correlated with January and February.

Table 3.11. Correlation Matrix for SS at Inlet

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
January	1.00	0.50	0.52	0.43	0.23	-0.09	0.35	0.09	0.10	0.52	0.41	-0.20
February	0.50	1.00	0.99	0.31	0.55	-0.10	0.38	-0.22	0.13	0.39	0.61	-0.40
March	0.52	0.99	1.00	0.32	0.54	-0.07	0.44	-0.20	0.13	0.40	0.64	-0.37
April	0.43	0.31	0.32	1.00	0.72	0.48	0.61	-0.12	0.06	0.68	0.31	-0.17
May	0.23	0.55	0.54	0.72	1.00	0.38	0.34	-0.11	0.29	0.57	0.47	-0.13
June	-0.09	-0.10	-0.07	0.48	0.38	1.00	0.24	-0.09	0.33	0.25	-0.04	0.24
July	0.35	0.38	0.44	0.61	0.34	0.24	1.00	-0.05	0.05	0.39	0.58	-0.03
August	0.09	-0.22	-0.20	-0.12	-0.11	-0.09	-0.05	1.00	0.79	-0.64	-0.45	-0.35
September	0.10	0.13	0.13	0.06	0.29	0.33	0.05	0.79	1.00	-0.44	-0.25	-0.33
October	0.52	0.39	0.40	0.68	0.57	0.25	0.39	-0.64	-0.44	1.00	0.69	0.28
November	0.41	0.61	0.64	0.31	0.47	-0.04	0.58	-0.45	-0.25	0.69	1.00	0.37
December	-0.20	-0.40	-0.37	-0.17	-0.13	0.24	-0.03	-0.35	-0.33	0.28	0.37	1.00

Table 3.12. Correlation Matrix for SS at Outlet

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
January	1.00	0.13	0.08	-0.07	-0.01	0.24	0.11	0.18	0.14	0.20	0.15	0.12
February	0.13	1.00	0.99	0.39	0.30	0.55	-0.22	-0.10	-0.20	-0.30	0.30	0.11
March	0.08	0.99	1.00	0.41	0.36	0.51	-0.24	-0.11	-0.22	-0.33	0.28	0.06
April	-0.07	0.39	0.41	1.00	0.75	0.44	-0.17	0.05	-0.63	0.03	0.29	-0.30
May	-0.01	0.30	0.36	0.75	1.00	0.46	0.30	0.53	-0.36	0.49	0.46	0.10
June	0.24	0.55	0.51	0.44	0.46	1.00	0.45	0.52	-0.02	0.10	-0.07	-0.05
July	0.11	-0.22	-0.24	-0.17	0.30	0.45	1.00	0.74	0.12	0.72	-0.06	0.41
August	0.18	-0.10	-0.11	0.05	0.53	0.52	0.74	1.00	0.38	0.62	0.06	0.32
September	0.14	-0.20	-0.22	-0.63	-0.36	-0.02	0.12	0.38	1.00	-0.05	-0.35	-0.04
October	0.20	-0.30	-0.33	0.03	0.49	0.10	0.72	0.62	-0.05	1.00	0.52	0.58
November	0.15	0.30	0.28	0.29	0.46	-0.07	-0.06	0.06	-0.35	0.52	1.00	0.63
December	0.12	0.11	0.06	-0.30	0.10	-0.05	0.41	0.32	-0.04	0.58	0.63	1.00

It indicates by knowing the BOD_5 concentration in January and February will give good indications to concentrations of BOD_5 in other months. The same is true for all the other months except December. So at inlet all the months are very well correlated. From the table it can be seen that January is well correlated with all the month except the month of August. In case of February it is not well correlated with the month of August and September but besides them all are fairly correlated. In case of March the months August, September and November are poorly correlated. In case of April almost all the months are fairly correlated. May is fairly correlated with other months except August and September. June and July is well correlated with other months. August is only correlated with June, July, September and November. September is fairly correlated with January, April, June, July, August, November and December. In case of October the correlation is fair with all the months except August and September. November is fairly well correlated with all the months except in the month of March. December is well correlated with almost all the months.

3.3.4 Correlation Matrix for SS

This correlations are given in 3.11 and 3.12

From the above table it can be found that the values of January is fairly well correlated with February, March, April, July, October and November. February is correlated with January, March, May, July, October, November and December and poorly correlated with April, June, August and September. Other months can be considered similarly i.e. correlation is good when correlation co-efficient value is 0.35 or greater and poor when the correlation coefficient is less than 0.35. The values in the above table are categorized as previously described which is correlation is good when correlation co-efficient is 0.35 or greater and correlation is poor when coefficient is less than 0.35.

Conclusion and Recommendations

A study was conducted to assess "the performance of the Pagla Sewage Treatment Plant". Relevant data were collected from published reports, books etc. Field visits were also carried out. Wastewater characteristics data in relation to BOD and SS was collected from the Pagla Sewage Treatment Plant and then was analyzed. Following conclusions may be drawn on the performance of Pagla Sewage Treatment Plant. [10]-[13] emphasizes on the adverse impacts of climate change over Bangladesh and how the densely populated country will be facing huge challenge in combatting these climate change related problems in the coming futures.

4.1 Conclusions on Pagla Sewage Treatment Plant

- The sewage treatment plant at Pagla operates under a flow considerably lower than the design capacity.
- The treatment plant serves one-third demand of Dhaka city in relation to treating and disposing wastewater.
- From the recorded data it can be seen that the quality of incoming flow is very strong compared to the design condition. In addition, presence of toxic chemicals in the influent resulting from industrial effluents reduces the performance of the plant. These chemicals may be responsible for death of active bacteria.
- Normal operational effective depth of the lagoons is about 1m, but these are designed for 2 m.
- About 0.3 m sludge or suspended solids settled on the bottom of the lagoons, which indicates negligence in operation and maintenance practice.
- At present, one of the impeller at the Inlet structure has been found out of order. The maintenance cost is so high that it requires special consideration to repair.
- The study result indicates that the effluent BOD_5 is higher (occasionally 240mg/l) in many cases than allowable limit (50 mg/l). The higher value is not

unusual, as influent BOD_5 is as much high as 1200 mg/l specially 1999 and onwards. The treatment plant is designed for domestic sewage assuming influent BOD_5 value 200-250 mg/l.

- Laboratory facilities are not adequate enough to monitor the quality of wastewater at different points.

4.2 Suggestion for Improvement

- Recording data in computer format in user friendly interface is recommended.
- Immediate cleaning of the lagoons is highly recommended.
- Using the sludge for productive purpose (making of low quality brick) is recommended.
- Improvement of the laboratory facilities is also recommended.

4.3 Recommendation for Further Study

- The reasons of high BOD_5 value of wastewater should be identified. Septage condition may be one of the reasons.
- Further studies is recommended to assess the actual sources of unauthorized intrusion of wastes such as industries within the Dhaka city, their type, effluent quality and the discharge points. If the industry discharges its effluent to the city sewerage network, it must comply with the Environmental Quality Standard of Bangladesh.
- According to IWM study (January,2006) it is found that in critical dry season the water quality in peripheral rivers of Dhaka (Buriganga, Lakhya, Turag, Balu and Tongi Khal) deteriorates in such a way that it requires extensive treatment prior to using for consumptive purpose. As Pagla Sewage Treatment Plant covers one-third of the wastewater in Dhaka city further option for construction of more treatment plant should be considered to keep the water quality in peripheral rivers into reasonable level.
- As sewage contains elements of industrial toxics COD measurement is recommended.
- It is recommended that the design retention time (2.02 hr) for primary sedimentation tanks and particularly for lagoons (7 days) be verified. It may also include assessing the performance of the lagoons keeping effective sewage depth 2 m.
- Effectiveness of the chlorination system at the outlet of the Pagla Sewage Treatment Plant may also be studied.

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