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STUDY OF PAPER MILL FOR WATER REÇYCLING, HAYATABAD INDUSTRIAL ESTATE, PESHAWAR

MOHAMMAD NAFEES[1], WISAL SHAH[1], HAYA KHAN[1] & ZAHIDULLAH[2]

[1]Department of Environmental Sciences University of Peshawar.
[2]Department of Environmental Sciences, Alama Iqbal Open University, Islamabad.

Abstract: This study was designed to explore possibility of introducing the concept of wastewater recycling in the paper mill. The main objective of this study was to investigate how to improve the quality of pulp and paper mill wastewater effluent to make it fit for recycling inside the mill. For this a comprehensive study was conducted at Olympia paper mill, Hayatablad. In first step different units operation and pollution points were examined and compiled the results. By comparing with Pakistan National Environmental Quality Standards the results were above the permissible limits and direct discharge is not environment friendly. To make it fit for re-use chemical treatment method (Alum, Lime) was applied. Different doses of alkalinity and alum were applied by using simple jar test. It was found that alum dose with 8 ml alum and 4 ml alkalinity of 1000 mg/l each give optimum results for paper machine effluents. For pulp synthesis (SP-plant) section need 26 ml of alum with 13 ml Alkalinity of 1000 mg/l each gave optimal results. The digester water was found a little difficult and need 74 ml and 37 ml of alum and alkalinity respectively of 1000 mg/l strength. To keep paper mill environment friendly, it is therefore strongly recommended to re-cycle the effluent of paper machine and SP-plant, and release the effluent from digester after treatment.

Key Words: Coagulation, Alkalinity, Re-Cycling, Water Quality Parameters, National Environmental Quality Standards (NEQS).

Introduction

Hayatabad Industrial estate is the 3rd largest industrial estate in Khyber Pakhtunkwa (KP). It is scattered over an area of 868 acre. According to a study conducted in 2006 there were 272 industrial units operational (SDA, 2006). Since its inception it never happened to keep all established units operational. The various hurdles included availability of the raw material, energy and labor (Nafees, 2004). Instead of this it pose negative impacts on environment (Sardar et al 2002). Water pollution is a serious aspect affecting Shalam River, which ultimately join Kabul River. Another problem is large scale water consumption (Zahidullah, 2009). To over come on water pollution two treatment plants have been installed, one in Haytabad and the other on Charsada Road., but none of these are operational. In this way the untreated water joining Kabul Rive the ultimate sink of HIES's effluents. Environmental Protection Agency (EPA), Peshawar had initiated various regulatory measures in the form of Environmental Impact Assessment, Environmental Monitoring (IUCN-DEPM, 1994). Although the water exceeds the NEQS, still there are no regulatory measures taken against any industry (Sail et al, 2006).

To reduce pollution at source, in 1994 United Nation Environment Program introduced the concept of clean processing and was also applied in the diary sector in Pakistan as an alternative to end of pipe treatment (ETPI, 2000). Under the concept of clean processing preventive measures were adopted in which pollution is controlled at source. The major focus areas are recycling and re-use. The idea behind this was that end of pipe treatment seems expensive and need some extra investment while clean processing is modification in the installed unite in which the input resource like water is saved by introducing the concept of re-cycling and re-use. In Pakistan this technology was introduced in Milk processing and petroleum (Ozbay and Demirer 2007).

To over come on water shortage various study have been conducted to starts the concept of clean processing also called pollution prevention and over come on the water wastage. Marble industry is one of the example in which water wastage was reduced by

20-30 times (MTL, 2003). Similarly rubber and plastic industries was studied to over come on resource waste like electricity and water (Humera *et al*, 2002).

Paper mill is one of the industries where water is the main input and stand 3rd in terms of water usage (Avsar and Demirer, 2006). Water consumption can be optimize by introduction recycling and re-use. Paper Mill is in the list of top ten pollution industry coming at serial number six (Muna and Sreekrishnan, 2001). The objectionable most parameters are the suspended load and high COD contents, which affect river fauna by decreasing Dissolve Oxygen (DO) level (Cox, 2003). End of pipe treatment is one of the options, which is considered as expensive. The various treatment options tried include primary treatment, secondary treatment, and advance treatment including membrane separation, electro-dialysis, ion exchange etc.

For paper mill El-Bestawy et al (2008) recommended a two stage treatment i.e. coagulation process followed by biological treatment. The process to separate suspended load and re-cycle the waste water was completed in three different stages, coagulation, chemical oxidation with hydrogen peroxide and biological treatment. This usually appeared expensive. Pokhrel and Viraraghavan, (2004) separated each processing step highly supported coagulation process and reported 96% COD removal from the pulp machine. Bleaching effluents was found difficult which need an integrated approach by adding further chemical and biological treatment (Verenich et al 2001). Digester is another difficult area with high BOD, COD and colour contents. The digester effluent need advance chemical treatment by applying activated carbon, which is an expensive technology. To overcome the cost a cheep source in the form of petroleum coke was used as source of activated carbon (Shawwa, et al 2001).

Each paper mill has its own composition and generates different effluents and need proper exploration with different available techniques. This study is an attempt to analyze Olympia Paper Mill for water recycling.

Methods and Materials

Olympia paper mill is one of the largest industrial unit in HIE Peshawar. It is equipped with facilities to prepare paper from both, virgin cellulose source and recovered (waste paper) cellulose sources. The paper mill under study using digester occasionally. During the study the paper mill was using recovered cellulose source and was evaluated for clean processing by applying the following methodology.

Sample Collection

After visiting the industry three sample points were identified,1) Pulper, 2) the paper machine, and 3) digester. Composite sample consist on eight grab samples (with one hour interval) were collected from each point. The collected grab samples were mixed in plastic bucket. After mixing one litter composite sample was taken.

Sample Analysis

The composite samples collected from the three different points were analyzed for pH, Conductivity, Total Solids (Dissolved, suspended, organic and inorganic) by following standard Methods for the examination of water and waste water (APHA, 1992).

Treatment

After analyzing the characteristics of waste water collected from different sections it was found to be high in Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD_5)). As mentioned earlier among the three effluent points the digester was major source of BOD_5 and COD due to high lignin contents. While the remaining two sections fine particles of pulp causing high BOD_5 and COD values. As it is usually in suspended form (coarse and fine pulp particles) and can be removed with the help of physical and chemical treatment (Rodrigues et al 2008).

In physical treatment, different options were reviewed, including filtration and sedimentation (Peavy et al 1985). Due to huge amount of waste water release with heavy suspended load the suitable method was found as sedimentation and chemical coagulation (Pokhrel and Viraraghavan, 2004).

To evaluate recovery of pulp, the sample was subjected to Jar-Test by applying different doses of coagulant and alkalinity (Peavy et al 1985). As the industry using Alum in the paper mill, one of the required raw-material, therefore, alum was used as coagulant. Similarly talc-powder is source of filler and CaO was used as source of alkalinity with the idea to keep the water fit for recycling inside the plant.

Results and Discussion

Water Usage

The paper mill situated in the Hayatabad Industrial estate is dependent on ground water with water characteristics as given in table 1. As estimated, about 2673.74 m^3 water is used per day. The amount varies in different sections. The average water consumption was found to be 75m^3/tons. of paper produced (Tables 2 & 3). The waste water is discharged in to Kabul River which is deteriorating aquatic life (Nafees et al, 2002) and also posed negative impact on availability of drinking water quantity in Peshawar City (Zahidullah, 2009).

The digester needed 144 m^3 water per day out of which 65% (93.6 m^3/day) is released and 35% (50.4 m^3/day) is retained for further processing. The S-P plant waste out 90% (972 m^3/day) of the water and retained only 10% (108 m^3) for further processing. Paper machine need comparatively more water and discharge almost all water, which is about 1450 m^3/day. In the final products about 8 to 10% moisture contents remained and not counted here (Table 3).

Table 1. Analytical results of fresh water used in Olympia paper mill of HIE Peshawar.

S.No.	Parameter	Units	Results	Method used
1	Colour	--	Clear	Visual
2.	Odour	TON	Nil	Threshold odor number (TON)
3.	pH	--	7.2	Digital pH-meter
4.	E.C	µs/cm	1058	Conductivity meter
6.	TSS	mg/l	Nil	Gravimetric
7.	TDS	mg/l	600	Gravimetric
8.	Turbidity	NTU	Nil	Instrumentation
9.	Alkalinity	mg/l	325	Titration.
10.	BOD_5	mg/l	8.0	Instrumentation
11	COD	mg/l	12	Reflux titration.

Table 2. Water Usage and production of waste water at different points of the paper mill (m^3/ton).

Unit operation	Water usage	Waste water discharge	Water remain for further processing
Digesting Chamber	4.00	2.60	1.40
S-P Plant Chamber	30	27.00	3.00
Paper Machine	41.00	40.26	0.74
Total	75.00	69.86	5.14

Table 3. Water Usage and production of waste water at different points of the paper mill per day (m^3/day).

Unit operation	Water consumed per day	Waste water discharge	%age of the total	Water remains for further processing
Digesting Chamber	144.00	93.60	3.76	50.40
S-P Plant Chamber	1080.00	972.00	39.04	108.00
Paper Machine	1449.74	1423.84	57.19	25.90
Total	2673.74	2489.44	100.00	184.30

Table 4. Analytical results of various sections of paper mill effluent of HIE Peshawar.

S.No.	Parameter	Units	Digester process sewage drain.	SP plant drain.	Paper Machine	Pak-NEQS
1.	T (C^0)	C^0	65	30	30	40
2.	Flow	m^3/h	60	40	60	NA
3.	Colour	--	Black	yellow	Grayish	NA
4.	Odor	TON	Objectionable	Objectionable	objectionable	NA
5.	pH	pH-Scale	8.7	6.2	5.7	6-10
6.	E.C	µs/cm	1255	1055	850	NA
7.	TSS	mg/l	1480	1220	1920	150
8.	TDS	mg/l	2800	1000	1600	3500
9.	Turbidity	NTU	145	144	152	NA
10.	Alkalinity as $CaCO_3$	mg/l	650	430	475	NA
11.	BOD_5	mg/l	560	440	514	80
12	COD	mg/l	980	890	900	150

NA Not Available

Physicochemical Characteristic

The wastewater quality is varying form section to section. Digester was found the polluting most when compared with other sections. It has got a blackish colour with high pH values. Temperature is an important factor, which affects aquatic organisms. Although, Temperature it is not used to evaluate the water quality directly but it affects a number of other parameter (Clot, 2006). It changes the solubility of essential gases like oxygen in water. Changes in temperature also influence the metabolic rate (Tromans, 1998). According to NEQS the maximum temperature for industrial discharge is 40C^0 (GOP, 1997).The effluents temperature of Olympia paper mill was in the range of 30–60°C was found in the digester drain of Olympia paper and board mill. This is high form Pak-NEQs (Table 2). But the discharge to Kabul River is indirect through *Budni-Nullah* and cooled down on the way to join Kabul River situated as a distance of more than 20 Km.

For pH the Pak-NEQs range is 6-10 while that of various sections of paper mill the range was 5.7 – 8.7 and was within the permissible range.

The BOD_5 and COD values of digester were 560 and 980 mg/l respectively. The total dissolved contents were 2800 mg/l. the high pH value can possibly be attributed to the use of caustic soda. While the BOD_5 and COD are attributed to lignin contents (Table 4). Wastewater of SP plant contains small plastic and cellulose particles as suspension. The main chemicals used in this section include bleaching agents and alum. This decrease the pH of the solution and also affected collides (small cellulose particles) that remain suspended and are the main hurdles in water recycling. Wastewater from paper machine contain high amount of cellulose fibers when compared with that of SP-plant due to which its BOD_5 and COD contents were very high.

Other parameters like turbidity, alkalinity and conductivity not define in the Pak-NEQS and were measures as indicator for treatment.

In summary the important parameters were BOD_5 and COD and both were high when compared with Pakistan National Environmental Quality Standards (Pak-NEQS).

Physicochemical treatment

Wastewater samples of paper machine with initial pH value 6.45 and Electrical conductivity 1413us/cm, adding 2-5ml of alkaline solution to raise the pH above 7 because in coagulation the pH of water is important (Peavy, 1985). Acidic water with pH value of 5-6.5 are often difficult to clarify needing treatment with alkalinity and coagulant doses which tend to be narrowly critical water of pH 6.2-7 with a reasonable degree of alkalinity (double of coagulant react well to the aluminum sulphates (Smethurst, 1988).

Various alkalinity and coagulation doses were applied. For this a stock solution of 1000 mg/l was prepared. Table 5 to 7 shows that a combination of 8, 26 and 74ml of coagulant (Alum) with 4, 13 and 37ml of Alkalinity gave maximum suspended solid removal

for effluents of paper machine, SP-plant and digester respectively. The required settling times were 6, 10 and 20 minutes/25 cm for paper machine, SP-plant and digester respectively. As clear from tables 5-7 a decrease in settling time can be achieved by increasing coagulant dose along with alkalinity but side wise there is increase in pH which needs adjustment at latter stage in SP-plant by adding more alkalinity.

The water of digester is a comparatively difficult to treat as it is alkaline and need less alkalinity to be added. The colour still remains mainly because of dissolved organic and inorganic substances. Therefore, extra treatment will be required to stabilize it. It can not be recycled after coagulation only and would require additional retention time for stabilization.

The wastewater from paper machine and SP-plant could also be made recyclable inside the Mill. Similar procedure adopted for the SP plant wastewater and digester process wastewater.

Table 5. Coagulant and alkalinity dosages (of 1000 mg/l each) and their efficiency for Paper Machine wastewater.

S.No.	Coagulant (ml)	Alkalinity (ml)	pH	E.cond (us/cm)	Settling time (min) for 25 cm	Settling solid (% age)
1	0	0	7.2	1298	30	60
2	2	1	7.2	1284	25	60
3	4	2	7.2	1338	15	60
4	6	3	7.4	1350	8	80
5	8	4	7.4	1340	6	80
6	10	5	7.3	1343	5	80
7	12	6	7.3	1340	5	90
8	14	7	7.4	1339	5	90-95
9	16	8	7.4	1324	5	95
10	18	9	7.3	1322	5	95
11	20	10	7.2	1322	5	95-98

Table 6. Coagulant and alkalinity dosages (1000 mg/l each) and their efficiency for S.P plant wastewater.

S.No.	Coagulant (ml)	Alkalinity (ml)	pH	E.cond (us/cm)	Settling time (min)	Settling solid (% age)
1	0	0	7.2	1682	25	10
2	2	1	7.2	1752	25	10
3	4	2	7.2	1700	20	10
4	6	3	7.5	1660	15	20
5	8	4	7.6	1650	15	20
6	10	5	7.6	1625	15	20
7	12	6	7.6	1594	15	25
8	14	7	7.6	1587	15	40
9	16	8	7.6	1580	15	40
10	20	10	7.6	1576	15	40
11	22	11	7.4	1573	15	60
12	24	12	7.2	1564	10	80
13	26	13	7.2	1558	10	90
14	28	14	7.2	1552	8	95-98
15	30	15	7.2	1545	8	98

Table 7. Coagulant and alkalinity dosages (1000 mg/l) and their efficiency for digester wastewater.

S.No.	Coagulant (ml)	Alkalinity (ml)	pH	E.cond (us/cm)	Settling time (min/25 cm)	Settling soli (% age)
1	0	0	8.5	1968	120	20
2	2	1	8.5	1700	120	20
3	4	2	8.5	1720	100	30
4	6	3	8.5	1698	90	30
5	8	4	8.5	1694	90	30
6	10	5	8.2	1680	90	30
7	12	6	8.2	1678	90	30
8	14	7	8.2	1670	90	30
9	16	8	8.2	1679	80	30
10	18	9	8.2	1666	80	30
11	20	10	8.2	1666	80	30
12	22	11	8.2	1666	80	30
13	24	12	8.2	1666	60	40
14	26	13	8.5	1666	60	40
15	28	14	8.3	1666	60	40
16	30	15	8.3	1660	60	40
17	32	16	8.3	1650	60	40
18	34	17	8.3	1650	60	40
19	36	18	8.3	1650	60	40
20	38	19	8.0	1655	60	40
21	40	20	8.0	1655	60	40
22	42	21	8.0	1655	60	40
23	44	22	8.0	1655	60	40
24	46	23	8.0	1650	60	40
25	48	24	8.0	1650	60	50
26	50	25	8.0	1650	60	50
27	52	26	8.2	1650	60	50
28	54	27	8.2	1650	45	50
29	56	28	8.2	1650	45	60
30	58	29	8.0	1650	45	60
31	60	30	8.0	1645	30	60
32	62	31	8.0	1645	30	60
33	64	32	7.89	1645	30	60
34	66	33	7.89	1645	25	60
35	68	34	7.89	1645	25	80
36	70	35	7.89	1645	25	80
37	72	36	7.89	1645	25	80
38	74	37	7.89	1645	20	80
39	76	38	7.89	1645	20	90
40	78	39	7.89	1645	15	90

Table 8. Analytical results of Olympia paper mill effluent of HIE Peshawar, after treatment.

S.No.	Parameter	Units	Digester wastewater	SP Plant wastewater	Paper machine
1	Colour	--	Brownish	Cloudy	Cloudy
2	Odor	--	N-O*	N-O*	N-O*
3	PH	--	7.8	7.5	6.5
4	E.C	µs/cm	2200	1056	1055
5	TSS	mg/l	700	18	10
6	TDS	mg/l	1169	1012	871
7.	Turbidity	NTU	25.0	16.0	15.0
8	Alkalinity	mg/l	525	400	425
9.	BOD5	mg/l	20	12	14
10.	COD	mg/l	80	25	28

*N-O non objectionable.

Water Quality after Treatment

The final results shows that removal of suspension, which mostly organic, the water from Paper Machine and SP-plant become suitable to be re-use in the paper mill (Table 8). Total dissolved solid appeared high which is mainly due to alum the required raw-material for paper making (Table 8). The wastewater of digester after treatment can not be recycled inside the plant but can be release after treatment when compared with Pak-NEQS as given in Table-4.

Conclusion

Paper mill effluents are high in COD and BOD content. After dividing the plants into three processing units, digester, SP-Plant and Paper Machine it can be concluded that the effluents of digester is high in pollution load and difficult to treat. While that of SP-plant and Paper Machine, which is 96% of the total effluent content, can be treated and used inside the plant. This will release pressure on ground water resource as will as reduce water effluent by 96%. The water of digester which is 3.76% if released directly will contribute to water pollution therefore, a pre-treatment is suggested before release.

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