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Wastewater Management and Resource Recovery in Hard Paper Industry: A Case Study

[1]R. Abdel Wahaab, [2]A. K. Moawad and [1]Enas Abou Taleb

[1]Water Pollution Research Department, National Research Center,Giza, Egypt
[2]Civil Engineering Department, Faculty of Engineering, Al-Azhar University, Cairo, Egypt

Abstrct: In Egypt, the necessity of recycling of refused paper has an economical aspect for water reuse, in-plant waste control and by- product recovery. The characteristic wastewater stream obtained from four successive composite samples showed high values of COD, BOD and TSS. COD value ranged from 960 to 2300 mg/l, with an average value of 1505 mg/l. The corresponding BOD value ranged between 350 and 1059 mg/l, with an average value of 607 mg/l. Total suspended solids (TSS) and turbidity (NTU) ranged from 652 to 951 mg/l and from 167 to 380 NTU, respectively. Treated effluent characteristics using Alum, aluminum chloride and ferrous sulfate at optimum condition showed that the removal efficiency of COD values were 94.4% and 74 % for alum and ferrous sulfate, aluminum chloride, respectively. Corresponding BOD removal values were 91.1% and 85.2 %, respectively. Residual COD and BOD were 85 mg/l and 50.5 mg/l for alum, respectively. Higher concentration for both residual COD (380 mg/l) and residual BOD (85.2 mg/l) were recorded in case of ferrous sulfate coagulation. It is obvious that using alum as a coagulant is more economically and technically. Based on the obtained results, two treatment alternatives were established. A closed water circuit is achieved, no wastewater leaves the processes. The treated effluent is then utilized to almost 100 Complete recycle of sludge/slurry from the chemical treatment processes were also achieved, the manufacture plant will leave no waste at all.

Key words: Board paper · Chemical treatment · Pollution prevention · Recycle

INTRODUCTION

Rapid industrialization in Egypt has created pollution problems, which were unknown no too long time ago. The uncontrolled disposal of the wastes not only results in potentially dangerous health and environmental threat, but also wastes raw materials and energy. Therefore, in an attempt to tackle these problem, new pollution control legislation has been issued.

Act of 93/1962 and 48/1982 as well as Ministerial Decree of 649/1962 and 8/1983; and lastly Decree no.44/2000, are amongst other Egyptian regulations specifying the strength and the conditions of industrial waste disposal. A side from these regulations, the day in and the day out reiterated warnings of environmental pollution, have motivated Egyptian researcher to deal with such effluents as a challenging problem [1].

In Egypt, the increase in paper consumption; is reach to 1017.5 thousand tons in year 2010 [2]. Pulp and paper mills generate varieties of pollutants depending upon the type of the pulping process. This indicates that million tons of paper may be needed to be recycled therefore the re-pulping process may grow up in the near future. Many activities produce refuse paper such as: presses, institutional firms, news print etc. The necessity of recycling of refused paper in Egypt has two important aspects. First aspect is the environment where paper mill and re-pulping of recycled paper and water provide conditions for a rapid growth of microorganisms. They contain copious amounts of biodegradable matter from wood, starch and other raw materials. Second is the economical aspect for water reuse and in-plant waste control. By- product recovery frequently accompanies water reuse [3,4].

A variety of products are made from recycled paper. These include recycled printing and office papers, toilet paper towels, napkins, recycled newsprint, paperboard, cellulose insulation, roofing felt, cushioning

Corresponding Author: Dr. Rifaat Abdel Wahaab, Water Pollution Research Department, National Research Center, Postal Code: 12622, Giza, Egypt

material for packaging and molded pulp products such as egg cartons, packaging cartons[5]. Wastewater produced from the paper industry is complex in nature. The pollution in the wastewater of a paper mill depends on the raw materials, the type and the amount of filters and additives applied and on the degree circuit closure [6,7].

Combinations of anaerobic and aerobic treatment processes are found to be efficient in the removal of soluble biodegradable organic pollutants. Color can be removed effectively by fungal treatment, coagulation, chemical oxidation and ozonation. Chlorinated phenolic compounds and adsorable organic halides (AOX) can be efficiently reduced by adsorption, ozonation and membrane filtration techniques [8].

Electrochemical treatment of organic pollutants is a promising treatment technique for substances which are resistant to biodegradation. In this study an electrochemical treatment based on the principle of anodic oxidation was used to treat paper mill effluent [9].

As for environmental protection, two approaches are currently being taken in various industries to minimize environmental pollution. One approach is to adapt the traditional forms of waste control and management to new more stringent ecological requirements. This approach does not affect the amount of waste. The other approach is an active one as it strives to overhaul the processes in-plant to cut down or even avoid any wastes, altogether, or to make them less detrimental to the environment, or even to convert them to products which could be re-processed or stored under controlled conditions, etc. As seen, the objective with the second approach is to create processes and plants that will leave no waste at all. Waste-less processing or manufacturing is a major social and economic task. For one thing, when solved, it will undoubtedly add to the nation's economic wealth and industrial progress. For another, there will be a sound ecological interaction between production and the environment [10].

The main aim of the present study was to apply pollution prevention on the cardboard production process; and assess and investigate treatment options for wastewater that generated from production processes using chemical coagulation. These included the following objectives: Evaluate of the efficiency of the chemical treatment of wastewater using different coagulant and recycle of both treated effluent and the sludge produced into the production processes.

MATERIALS AND METHODS

The industrial activity under investigation is located near Aga city, Dakahlia Governorate in cultivated land. It produces cardboard used for handling table eggs. The cardboard production unit is integrated in a chicken farm and the cardboard is utilized for the eggs produced. The chicken farm and cardboard production unit are built on an area of 2000 m^3. Production rate from cardboard is 5 tons /day. Water used is about 125m^3 /day. Recycled water is about 85 m^3/day. Makeup water is 40 m^3/day. Raw wastewater discharged from the plant during the three working shifts, up to 40 m^3/day, has been recorded. The factory discharges its wastewater into sewage network without any type of treatment. In order to obtain the most economical treatment alternative, a management program was designed. This program included the following steps:

Description of the Manufacturing Processes: Cardboard production process is performed in a series of 4 consecutive stages namely re-pulping, purification and distribution, forming and drying. The production process is illustrated in Fig. 1 as follows:

- Re-pulping: Re-pulping is take place in 3 units operating in parallel. The raw materials, consisting of refused papers, are proportionate and mixed with water in a ratio of 96% water and 4% refused paper. The three re-pulpers are provided with mechanical stirrers aiding in pasting and re-pulping. This stage produces the re-pulped paper in the form of slurry.
- Purification and Distribution: In this stage the slurry is pumped from the re-pulpers to another large tank (distributor) provided with a skimmer to remove the un-pasted floating solids where it is recycled to the re-pulper again. The purified slurry is pumped from the distributor tank to the forming unit.
- Forming Process: During this stage the paste materials are formed by the aid of an automatic vacuum machine. In this case the pulp takes the final form of the cardboard.
- Drying: In this stage the formed product enters a drying furnace on conveyer and leaves from the dryer at the other end. The dried products are collected in groups, cased and stored.

Physico-chemical Characteristics of Wastewater: Composite samples from the end of-pipe effluent were collected intermittently for analysis. The physico-chemical

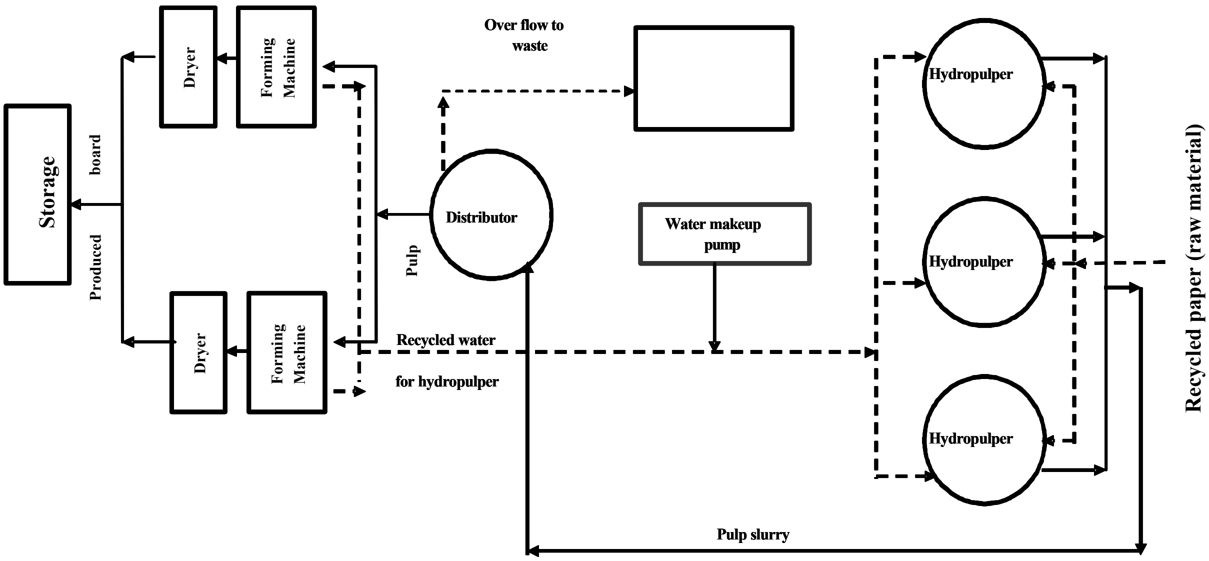

Fig. 1: Flow diagram of the production steps

characteristics of wastewater in this study covered the following measurements: pH, COD; BOD5, total solids, Total suspended solids; total dissolved solids; total phosphate, nitrate, surfactants, turbidity, sulphate and chloride.

Chemical Treatment: For chemical coagulation of wastewater, the Jar test procedure. Slurry-by product from water treatment plant and different coagulants was investigated. Three different coagulants were investigated to obtain the optimum operating condition. The coagulants investigated were Alum [$Al_2(SO_4)_3$], aluminum chloride ($AlCl_3$) and ferrous ions as coagulant.

In order to determine the optimum pH-range for each coagulant, different pH-values at a constant coagulant dose were examined. To study the effect of coagulant concentration, different coagulant doses were examined at the pre-determined optimum pH-value. Sample was placed under a state of rapid stirring (400 rpm), while the coagulant was added slowly to the solution under constant stirring for 60 seconds. The speed was reduced at a regular stepwise manner, covering a range of 100 rpm every 60 second until flocculation stage was reached. The speed was then maintained at 20-30 rpm for further 20 minutes, for optimum floc formation. The coagulation experiments were conducted with the jar test method.

Characteristics of the chemically treated effluent were carried out to identify the optimum operating conditions. Based on the obtained optimum operating conditions, a schematic diagram of the treatment option and the design parameters was developed. Physico-chemical analysis, unless specified, were carried out according to the American Standard Methods devised by APHA [11].

RESULTS AND DISCUSSION

In-plant Modification: This alternative implies the construction of two collection tanks for the industrial effluents emanating from water leakage during the re-pulping process. One of these two tanks will be in operation till it is completely filled then the industrial wastewater will be directed to the other one. Water from first tank is recycled to the re-pulped and same for the second tank subsequently. This alternative will reduce the makeup water by 25% and reduce chemical oxygen demand by 77%; from COD concentration 10025mg O_2/l to about 2300 mg O_2/l However, the wastewater from the factory still needs to treatment after applying the in-plant modification.

Wastewater Characteristics: Since there are no significant variations in waste flow and characteristics, four samples were found to be sufficient from the end of-pipe process. The four taken samples were collected during four different days of a month (composite sample). Table 1 displays the results obtained from each sample and their arithmetic mean.

The wastewater characteristics displayed in Table 1. Characteristic wastewater stream obtained from four successive composite samples showed higher values of

Table 1: Physico-chemical Characteristics of raw wastewater after in plant modification

	Sample No.				
Parameters (mg/l)	1	2	3	4	Average
pH-value	7.1	6.5	7.8	6.4	6.9
Chemical Oxygen Demand	1270.0	960.0	1490.0	2300.0	1505.0
Biochemical Oxygen Demand	350.0	450.0	570.0	1059.0	607.0
Total Suspended Solid at 105°C	850.0	652.0	870.0	951.0	831.0
Total Dissolved Solid(TDS) at 105°C	830.0	550.0	910.0	1085.0	844.0
Nitrate-NO_3	4.0	3.5	4.6	5.2	4.3
Surfactants	6.5	4.3	5.7	7.1	5.9
Turbidity	273.0	167.0	380.0	420.0	310.0
Sulphate	124.0	124.0	136.0	160.0	136.0
Chlorides	103.0	96.0	115.0	120.0	108.0
Total Phosphate	1.0	1.0	1.6	2.0	1.4

Table 2: Efficiency of chemical treatment for wastewater using different coagulants at optimum condition

		Treated Effluent					
		Alum (Aluminum sulfate)		Ferrous sulfate		Aluminum	
Parameters (mg/l)	Raw	(240 mg/l)	% R	(600 mg/l)	% R	Chloride (125 mg/l)	% R
pH-value	7.8	7.30	-	7.47	-	6.9	-
COD	1490.0	85.00	94.4	380.00	77.5	730.0	51.00
BOD5	570.0	50.50	91.1	84.00	85.2	230.0	59.60
TSS at 105oC	870.0	25.00	97.1	77.00	91.1	60.0	93.10
TDS at 105oC	910.0	230.00	74.7	630.00	30.8	450.0	50.50
Nitrate-NO3	4.6	2.80	39.1	4.10	10.8	3.1	32.60
Surfactants	5.7	3.80	33.3	4.50	21.1	5.1	10.50
Turbidity	380.0	10.50	97.2	19.00	95.0	23.0	93.90
Sulphate	136.0	73.50	45.9	117.00	14.0	89.0	34.55
Chlorides	115.0	31.50	72.6	86.0	25.2	110.0	4.20
Total Phosphate	1.6	0.92	42.5	1.30	18.8	0.9	43.20

chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids and turbidity. COD value ranged from 960 to 2300 mg/l, with an average value of 1505 mg/l. The corresponding BOD value ranged between 350 and 1059 mg/l, with an average value of 607 mg/l. Total suspended solids (TSS) and turbidity (NTU) ranged from 652 to 951 mg/l and from 167 to 380 NTU, respectively. Average TDS was 844 mg/l.

End Of-pipe Treatment: The main features of the suspended solids and colloidal matters in this type of wastewater demonstrates high stability and slow settle ability as indicated from the cone preliminary settling test through the indicating the difficulty of sedimentation. Chemical coagulation and sedimentation were applied. The selection of specific chemical depends on the availability and the cost of that chemical.

The coagulants investigated were alum, aluminum chloride and ferrous sulfate. All solutions were freshly prepared before carrying out the experiments. In order to determine the optimum pH-range for each coagulant, different pH-values at a constant coagulant dose was examined. To study the effect of coagulant concentration, different coagulant doses were examined at the pre-determined optimum pH-value.

Characteristic of the chemically treated effluent at optimum condition using alum, aluminum chloride and ferrous sulfate at optimum condition is recorded in Table 2. The results obtained showed that the removal efficiency of COD values were 94.4, 51.0 and 77.5 % for alum, aluminum chloride and ferrous sulfate, respectively. Corresponding BOD removal values were 91.1%, 59.6 % and 85.2 %, respectively. Residual COD and BOD were 85 mg/l and 50.5 mg/l for alum, respectively (Figures 2 and 3).

Consideration of the available results obtained from the chemical treatment process tends to show that the use of alum may secure the best purification effect and economically promising than both aluminum chloride and ferrous sulfate as coagulants.

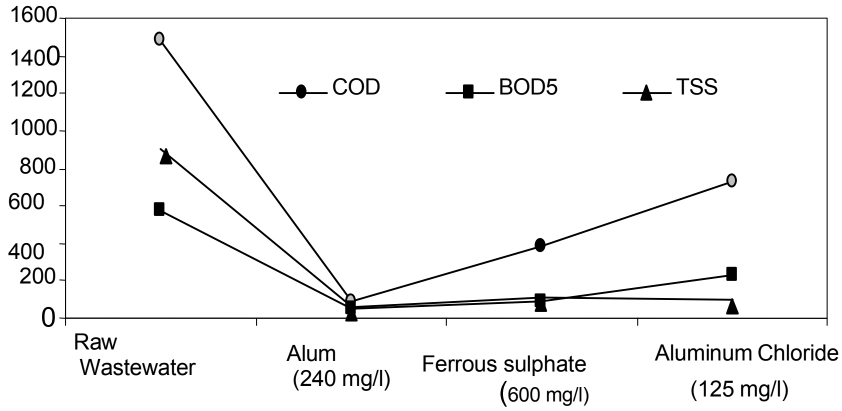

Fig. 2: Comparison between different coagulants in COD, BOD_5 and TSS removal efficiency at optimum condition

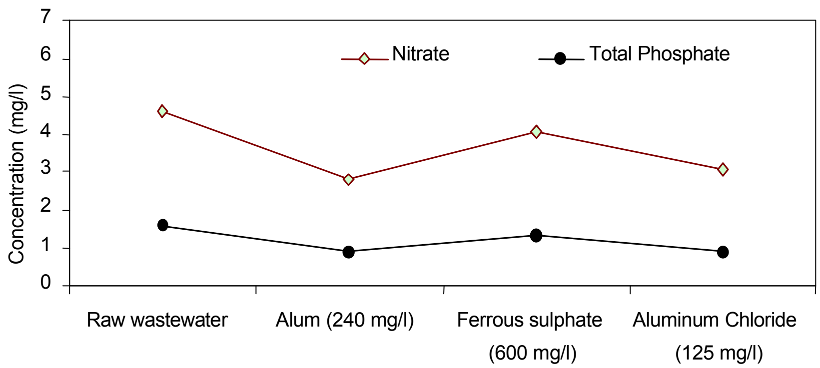

Fig. 3: Comparison between different coagulants in Nitrate and total phosphorous removal efficiency at optimum condition

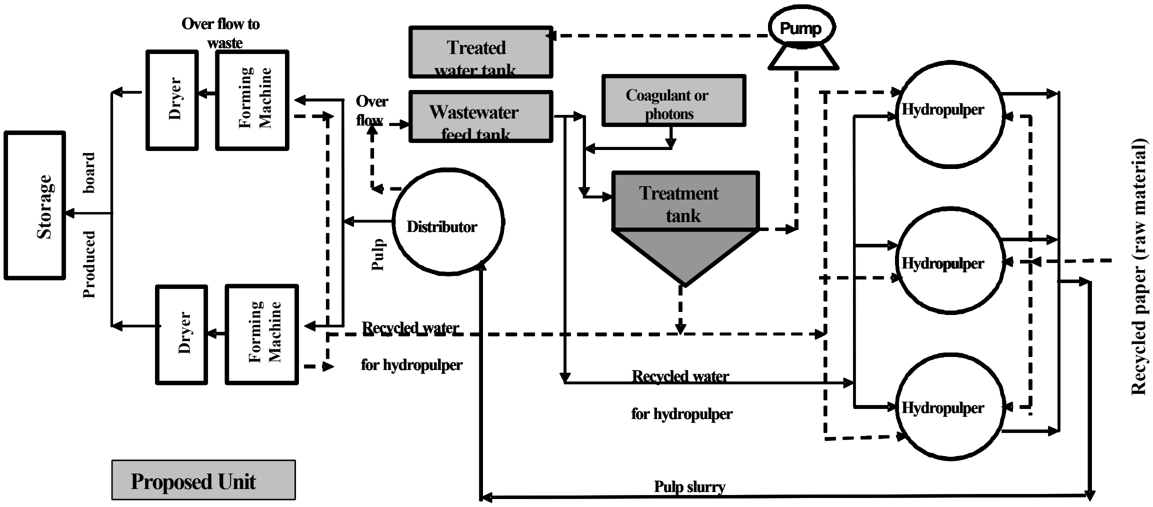

Fig. 4: Flow diagram of the production steps including the proposed unit

Treatment Alternatives

First Alternative: This alternative implies the construction of two collection tanks for the treatment of the industrial effluents emanating from water leakage during the re-pulping process. One of these two tanks will be in operation until it is completely filled, then the industrial wastewater will be directed to the other one. Water from the first tank will be recycled to the re-pulper. Despite the simplicity of the alternative, the recycling pump may generate faults.

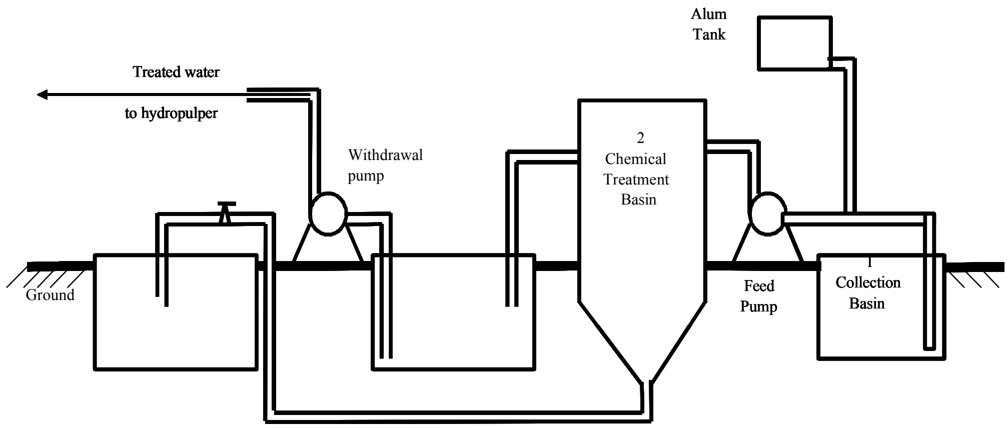

Fig. 5: Schematic diagram of the treatment unit

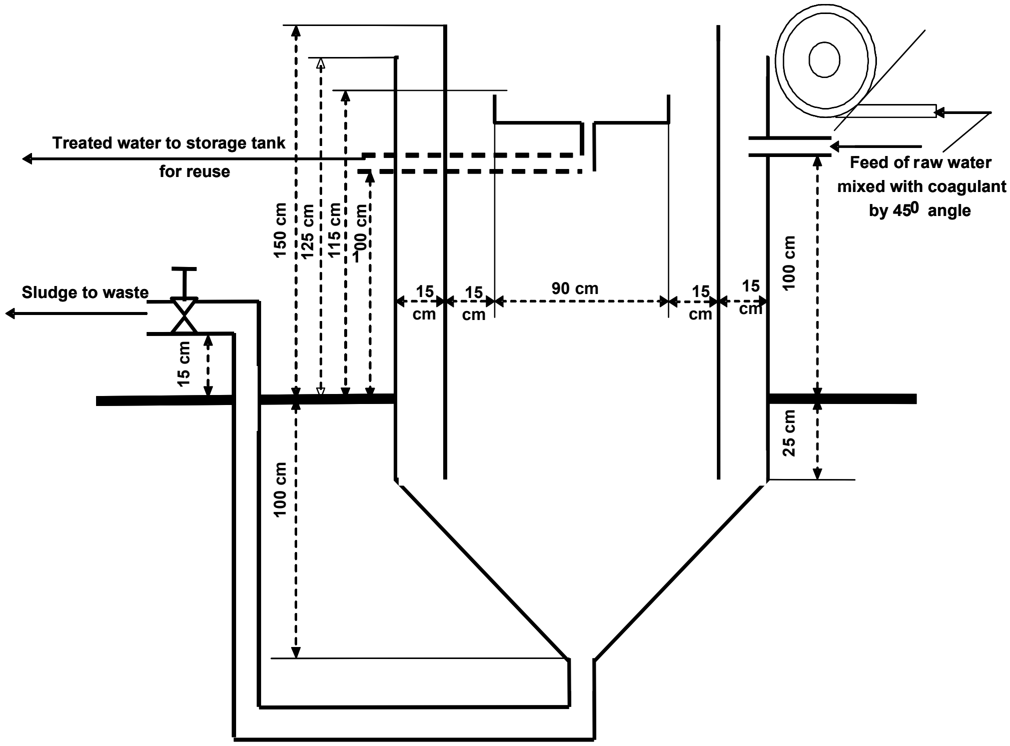

Fig. 6: Schematic Diagram of the Treatment Basin

Second Alternative: In this alternative a treatment system will be constructed as shown in Fig. 4 part of the manufacturing process and detailed in Fig. 5. The treatment will include three basins in addition to a chemical feeder tank. The function of each basin will be demonstrated as follows:

Basin (1): It is a concrete construction volume of 4 m3 whose dimensions are 2x2x1 and provide a suction pump with flow of 1.5 m3 /hr and 1 hp. The exit and entrance tube diameter is 2.54 cm.

Basin (2): It is the basic treatment tank. Its upper part is circular and the lower part is conical (tapered). All the dimensions of this basin are displayed in Fig. 6. This tank is designed for dual purpose (flocculation and settling).

The effective dose of alum is added and is rapidly mixed on line and completed by the impeding on the fans of the pump. Wastewater mixed with alum enters the tank tangentially at an angle of 45°.

In the tangential annular space the slow mix occurs and the formed flocks settle in the tapered bottom and are evacuated by the water head. Treated water overflows from the V-notch collector at the upper part of the internal cylinder.

Basin (3): Effluent collector No. (3) Receives the overflow. Its dimensions and construction material is the same as of basin (1). It is also provided with a withdrawal pump for recycling the treated water of the re-pulped

It was concluded that, consideration of the available results obtained from the chemical treatment process tends to show that the use of alum will secure the best purification effect and economically promising than both aluminum chloride and ferrous sulfate.

Pollution prevention measures via application of in-plant modifications to fully utilize the treated effluent in the manufacture process in a closed water circuit and complete recycling of sludge/slurry from the chemical treatment processes were successfully achieved. Therefore, it is worth to highlight that no wastewater leaves the processes and inconsequently no environmental impacts.

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