Journal of Environmental Protection and Ecology 3, No 3, 635–648 (2002)

Industrial pollution

CHARACTERISATION OF A JEAN-WASHING INDUSTRY PROCESSES' WASTE WATER AND BIOLOGICAL TREATABILITY

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Abstract. Due to the their complex waste water characteristics, it is necessary to make detailed researches and evaluations in every source to sustain active pollution control laws such as discharges standards. The structure of industry affects the waste water characterisation importantly, available profile of environmental pollution occurring from it should be determined in national base with making an observations and measurements at every source. In this framework, waste water characterisation becomes an essential part of waste water management strategies as well as the degree of treatment required. This study presents the results of detailed characterisation studies conducted on this plant production scheme and waste water quantity. In the scope of this study, firstly, the industry has been determined in terms of category and sub-category; secondly, waste water characterisation has been made and then process profile and pollution profile has been formed. When the results are evaluated, pH value of waste water originating from this industry washing and dyeing sewed jean fabric's is about 7 and it has suitable character for biological treatment in terms of BOD_5/COD ratio and C/N/P composition. Aerobic biological treatment process scheme has also been evaluated in terms of performance. As a result, activated sludge system removal efficiency is about 81-99%, which is in accordance with literature data.

Keywords: industrial pollution, textile industry, categorisation, sub-categorisation, process profile, pollution profile, re-use.

AIMS AND BACKGROUND

A detailed waste water characterisation should be conducted for the assessment of a waste water management strategy. This approach should also be adopted for textile effluents bearing specific and complex characteristics.

Sub-categorisation should be included in waste water management system for textile industry. 8 different sub-categories have been assessed for Turkey considering textile processing potential[1]. According to this classification, jean-washing industry is included in textile industry and since it has a dynamic structure with a number of production processes, various quality and quantity of waste water could be originated from it.

The change in quality is due to the variation in conventional parameters like

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BOD_5, COD and suspended solids. Table 1 shows the present sub-categories in Turkey with the waste water characterisation studies results[1]. As could be seen in Table 1, textile waste water exhibits significant changes due to the variation of the production facilities and the amount of water consumption from one industry to another.

Table 1. Sub-categories in Turkey with the waste water characterisation studies results

	Average concentration (mg/l)						
	COD	BOD	TSS*	oil and grease	Cr	phenol	sulphide
Wool washing	9000	3000	4000	3000	—	—	—
Felted fabric production	1200	300	200	—	—	—	1.0
Knit fabric finishing	1000	350	300	53	0.5	0.24	0.2
Stock and yarn finishing	1200	500	40	100	5.0	—	2.0
Woven fabric finishing	1200	650	300	14	0.04	0.04	3.0
Carpet finishing	2000	700	100	30	0.005	0.001	0.002
Non-woven fabric finishing	3850	1230	80	—	—	—	—
Jean washing finishing	1000	300	300	—	—	—	—

* Total suspended solids.

EXPERIMENTAL

Plant descriptions. The study generated and evaluated data from a textile plant processing cotton based sewed jean fabrics located at Corlu/Tekirdag. The plant operates six days a week, 250 days per year employing 590 people in 3 shifts a day. The process requires an average 672 m^3 of water per day supplied from local wells. It has a waste water treatment plant, composed of an equalisation basin, a neutralisation tank and activated sludge system with a 18 h hydrolic retention time, providing full treatment to the plant effluents before discharge into the adjacent creek which is one of the branch of Ergene river.

Methods. Measurements were made on composite samples which were taken from every process discharge at 3 shifts of a day. All analyses for conventional characterisation were performed as defined in Standard Methods[2]. pH, COD, BOD_5, NH_3-N, TKN, TSS, alkalinity, colour and conductivity were measured in this characterisation. Colour measurements were made on samples filtered through cellulose acetate membrane filters of pore size 0.45 µm and conducted on those with a Jenway 6105 UV visible model spectrophotometer. Absorbance measurements were carried out at 3 different wavelengths namely, 445, 540 and 560 nm, and then total colour values were obtained to sum up these values. 10 mm quartz cell were used in experiments. The unit of chromaticity number obtained from European Norm EN ISO 7887 was defined in m^{-1}. Standards obliged that chromaticity number should not exceed 15 m^{-1}. Measured values as adsorbent were converted to m^{-1} unit so that these values could be compared with the standard values. The following formula was used for converting the obtained values[3]:

$$\alpha = (A/d)f$$

where α is colour (m^{-1}); A – measured value on the spectrophotometer (Abs); d – cell width (mm); f – factor (1000).

Conductivity and total dissolved solids were measured namely on a hand type Hanna HI 8633 model TDS device and Hanna HI 8633 model conductivity meter supplied with calibrated electrodes. pH was also measured with a hand type WTW pH 330 (Set-1) model pH meter.

RESULTS AND DISCUSSION

Process profile. The selected plant sets a very representative example for the jean washing textile sub-category as it handles cotton based sewed jean fabrics. The plant operation involves 5 different processes, showed in Figs 1-5, respectively, all in batch systems. The striking feature of the operation, almost typical for this sub-category, is that the plant functions on fluctuating demands from the textile sector. Consequently, while a small group of processes is performed almost routinely, most others are much less frequent and the daily plant output, as far as production distribution and related waste water generation hardly ever reflect the entire process spectrum of the plant[4]. Therefore, the process profile of the plant, yielding the correlation between the amount of fabric processed and the rate of waste water generated, was evaluated as the daily averages of an in-plant survey for a period of a month. The average capacity of the plant was about 14 000 semi-processed goods per day with a waste water rate of around 672 m^3d^{-1} corresponding to a unit waste water generation of 49.5 l per semi-processed goods.

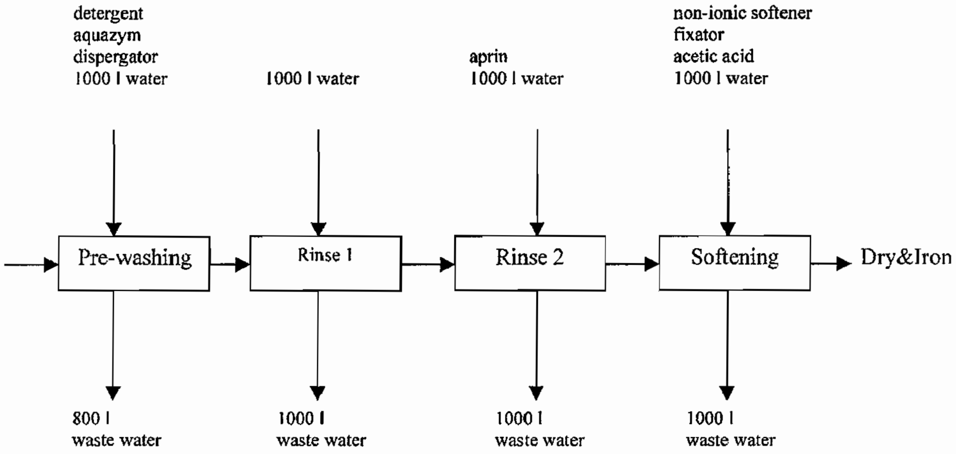

Fig. 1. Rinse wash process

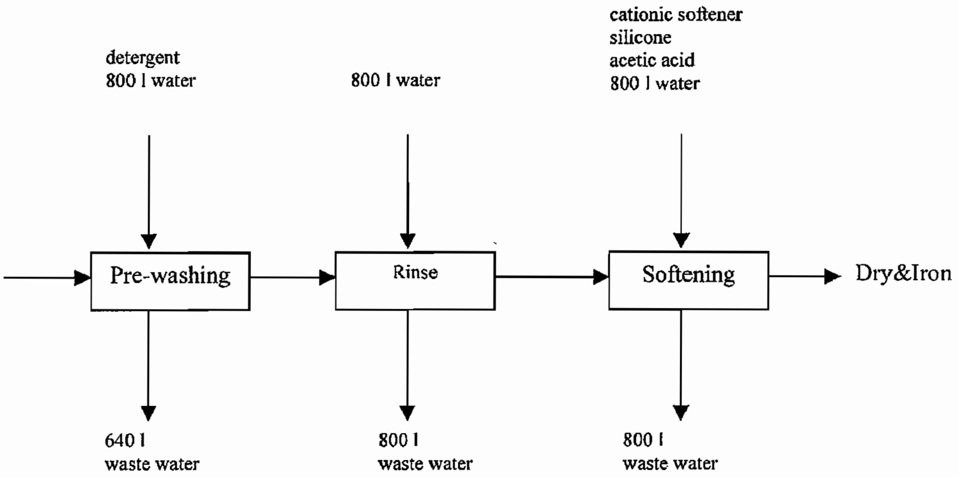

Fig. 2. Silicone washing process

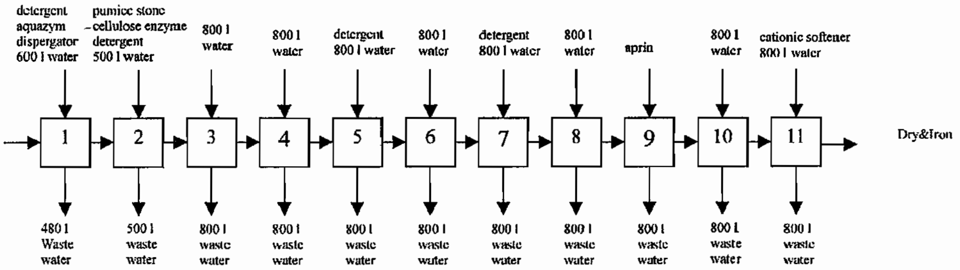

Fig. 3. Stone washing process
1 – pre-washing; 2 – stone washing 1; 3 – rinse 1; 4 – rinse 2; 5 – stone washing 2; 6 – rinse 3; 7 – stone washing 3; 8 – rinse 4; 9 – stone washing 4; 10 – rinse 5; 11 – softening

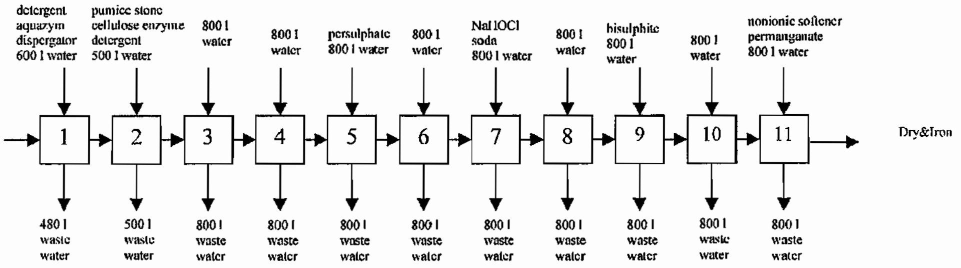

Fig. 4. Bleaching washing process
1 – pre-washing; 2 – stone washing 1; 3 – rinse 1; 4 – rinse 2; 5 – stone washing 2; 6 – rinse 3; 7 – bleaching washing; 8 – rinse 4; 9 – hypo neutralisation; 10 – rinse 5; 11 – softening

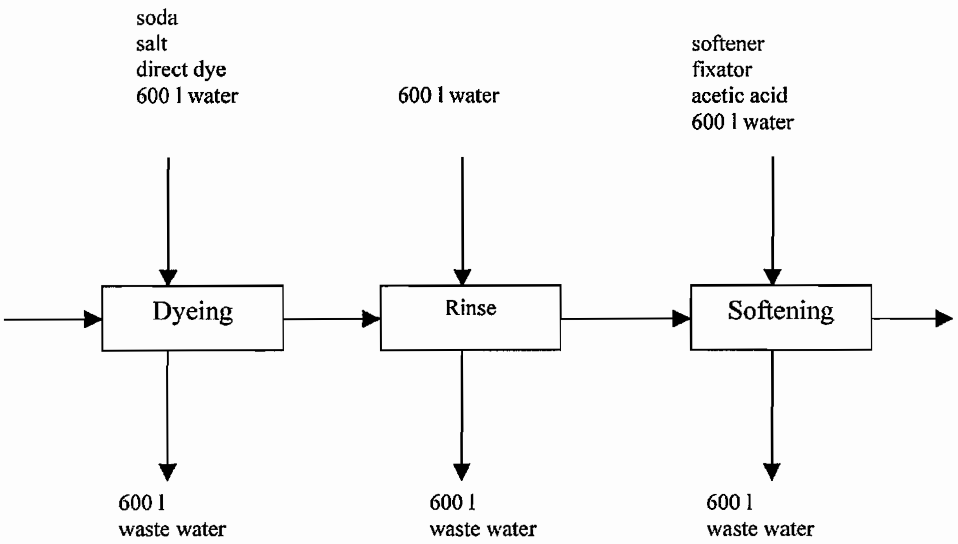

Fig. 5. Tint dyeing process

An important task at this stage is the selection of processes/waste streams that are likely to represent the waste water. Typical daily production data for these processes are listed in Tables 2A and 2B.

Table 2A. Process profile of the plant

Processes	Semi-processed goods (kg/charge)	Total average daily production (goods d^{-1})	Average daily charge number (charge d^{-1})	Waste water production			
				(m^3/charge)	(m^3d^{-1})	(l/goods)	(%)
Stone washing	70	4000	34	8.2	279	69.7	41.5
Rinse-wash	70	485	5	3.6	18	37.1	2.7
Silicone washing	60	2252	23	2.2	51	22.6	7.6
Bleaching washing	70	4000	34	8.2	279	69.7	41.5
Tint dyeing	70	2847	25	1.8	45	15.8	6.7
Total		13 584	121		672		100

Table 2B. Comparison of daily production data with waste water production

Processes	Daily production (kg/day)	(%)	Waste water production (m^3d^{-1})	(%)
Stone washing	4000	29.4	279	41.5
Rinse-washing	485	3.6	18	2.7
Silicone washing	2252	16.6	51	7.6
Bleaching washing	4000	29.4	279	41.5
Tint dyeing	2847	21	45	6.7
Total	13 584	100	672	100

As shown in Table 2B, stone washing and bleaching washing processes have the highest production ratio, approximately 60%, of the total production level of the plant, followed by tint dyeing, silicone washing and rinse washing processes with production ratios of 21, 16.6 and 3.6%, respectively. Stone washing and bleaching washing processes all appear in the day to day operation of the plant, greatly affect the quality of the overall plant effluent and discharge a total of 558 m^3d^{-1} of waste water, corresponding to 83% of the average total daily volume. On the other hand, although tint dyeing process has larger part in production than silicone washing process, it has a lower waste water production.

Waste water characterisation. This part of the experimental survey involved characterisation of the effluents from the selected processes in terms of conventional parameters that are relevant for treatment. Source-based waste water samples were collected both from each batch of washing and dyeing processes. The results are outlined in Table 3. From this characterisation pollution profiles were formed for total COD, TSS and NH_3-N parameters which are the significant conventional parameters for this industry.

Table 3. Conventional characterisation of selected process effluents

Processes	pH	COD (mg/l)	Colour (m^{-1})	NH_3-N (mg/l)	TKN (mg/l)	TSS (mg/l)	TDS (mg/l)	Conductivitiy (µS/cm)	Alkalinity (mg $CaCO_3$/l)
Stone washing	9.1	1351	84.6	1.12	5.04	182	530	1111	106.4
Rinse-wash	6.7	767	26.2	1.68	8.4	158	220	480	28.5
Silicone washing	5.7	544	5.1	-	6.72	84	213	455	21.3
Bleaching washing	7.1	855	115	2.24	4.48	1257	560	1210	44.8
Tint dyeing	5.3	695	8.3	14	106	82	1960	4080	25.8

The analysis of the data of Table 3 shows that the highest COD concentration has been measured in stone washing process and the lowest value has been observed in silicone washing process. This situation results from additional and more different chemicals used in stone washing process than in silicone process. When NH_3-N parameter is evaluated, the highest value has been measured in tint dyeing process because the structure used dyes containing non-hazardous azo-pigments. The other production processes have low values at about 1-2 mg/l. As can be seen the TKN values, because of used chemicals, organic parts of nitrogen, are rather high in all processes. On the other hand, it is observed that although COD value was measured higher in stone washing process than in bleaching process, TSS value on the contrary was found lower. At this point, it could be said that with a majority of organic substrates in stone washing process's waste water are in soluble form and also bleaching process's waste water's COD majority results from TSS.

Real interpretation of these values is only possible when coupled with relevant data on waste water generation rate and corresponding pollution load, conveniently expressed in terms of COD, TSS and NH_3-N. In this context, pollution load profiles indicating unit waste water flows and COD loads (organic loads), TSS loads and NH_3-N loads are outlined in Tables 4, 5 and 6, respectively.

Table 4. Pollution profile for COD

Processes	Total average daily production (goods d^{-1})	Average flow rate (m^3d^{-1})	COD			
			(mg l^{-1})	(kg d^{-1})	(g/goods)	(%)
Stone washing	4000	279	1351	377	94.25	54.7
Rinse-wash	485	18	767	13.8	28.45	2
Silicone washing	2252	51	544	27.7	12.3	4
Bleaching washing	4000	279	855	239	59.75	34.7
Tint dyeing	2847	45	695	31.3	11	4.6
Total	13 584	672	1024	689		100

Table 5. Pollution profile for TSS

Processes	Total average daily production (goods d^{-1})	Average flow rate (m^{3}d^{-1})	TSS			
			(mg l^{-1})	(kg d^{-1})	(g/goods)	(%)
Stone washing	4000	279	182	50.7	12.68	12.3
Rinse-wash	485	18	158	2.8	1.38	0.68
Silicone washing	2252	51	84	4.3	1.91	1.03
Bleaching washing	4000	279	1257	351	87.8	85.1
Tint dyeing	2847	45	82	3.7	1.3	0.89
Total	13 584	672	731.3	412.5		100

Table 6. Pollution profile for NH_3-N

Processes	Total average daily production (goods d^{-1})	Average flow rate (m^{3}d^{-1})	NH_3-N			
			(mg l^{-1})	(kg d^{-1})	(g/goods)	(%)
Stone washing	4000	279	1.12	0.31	0.08	15.3
Rinse-wash	485	18	1.68	0.03	0.062	11.9
Silicone washing	2252	51	-	-	-	-
Bleaching washing	4000	279	2.24	0.62	0.16	30.65
Tint dyeing	2847	45	14	0.63	0.22	42.15
Total	13 584	672	2.4	1.59		100

When pollution profile tables are evaluated, pollution loads of stone and bleaching washing process show a similar tendency. While 55 % of total COD loads are produced by stone washing process, about 35% are produced by bleaching washing process. On the contrary, 85 % of total TSS loads are produced by bleaching washing process and about 12 % by stone washing process. Furthermore, although tint dyeing process has the highest NH_3-N concentration in conventional characterisation, due to the water consumption in different quantity at processes, 42 % of total NH_3-N loads are produced by tint dyeing process, about 31 % by bleaching washing process, 15 % by stone washing process and 12% by silicone washing process. On the other hand, it could not be measured in silicone process. But when TKN value is examined, it could be said that all nitrogen constituents produced from this process are in organic form.

It was reported in literature that slightly loaded rinsing baths in many cases of textile dyeing could be reused without being treated[5]. Re-use criteria obtained from two different sources were given in Table 7, as one of them showed a diffused set of figures[6], the other had a stringent nature[7]. Source-based waste water conventional characterisation of these production processes was outlined in Table 2B. As can be seen from this table, waste water originating from silicone washing process, consisted of 7.6% of the total waste water in the production, could be re-used without necessity to be treated. On the other hand, re-use alternatives on other production processes' waste water will be researched in details in other studies.

Table 7. Re-use criteria for textile dyeing waste water

Parameters	Li and Zhao[4]	Hoehn[5]
pH	6.5-8	6.5-7.5
Total COD (mg/l)	0-160	< 50
TSS (mg/l)	0-50	<500
TDS (mg/l)	100-1000	
Conductivity (μS/cm)	800-2200	
Alkalinity (mg $CaCO_3$/l)	50-200	

Waste water treatment plant. This plant consists of:

– physical and chemical pre-treatment including coarse and fine grid, static screen, pumice stone sedimentation basin, pre-sedimentation basin, pumice stone sludge tank, equalisation basin and neutralisation basin, respectively;

– biological treatment, including activated sludge aeration basin and secondary sedimentation basin;

– sludge treatment and dehydration units, including sludge thickening basin and filterpress equipment (Fig. 6).

Grid channel stated in waste water treatment plant entrance has coarse and fine grids, holding and removing especially coarse pumice stones, escaped from used washing machine in production, with 10 mm and 7 mm openings, respectively. Pumice stones used in stone and bleaching washing processes are secondly separated from processes' waste water, namely in pumice stone sedimentation basin and pre-sedimentation basin. For a period of time, pumice stones holding basin having two compartments is cleaned by a hydraulic shovel. On the other hand, pumice stones, which could not be hold in former unit and precipitating in this basin, are collected in a conic shaped bottom by rotating scraper. Then pumice sludge is pumped to pumice stone sludge tank, consisting of steel construction and conic shaped bottom, by a membrane type pump continuously. After precipitation, pumice stone sludge is transported on a trailer for a period of time.

Homogenisation and flow equalisation are provided in equalisation basin. At the same time, equalisation basin is operated at variable level/invariable flow and a floated aerator is used for both aeration and preventing sedimentation. Waste water is pumped to neutralisation basin by two submerged pumps, each of one operated on standby. Pumps get start/stop with level control system.

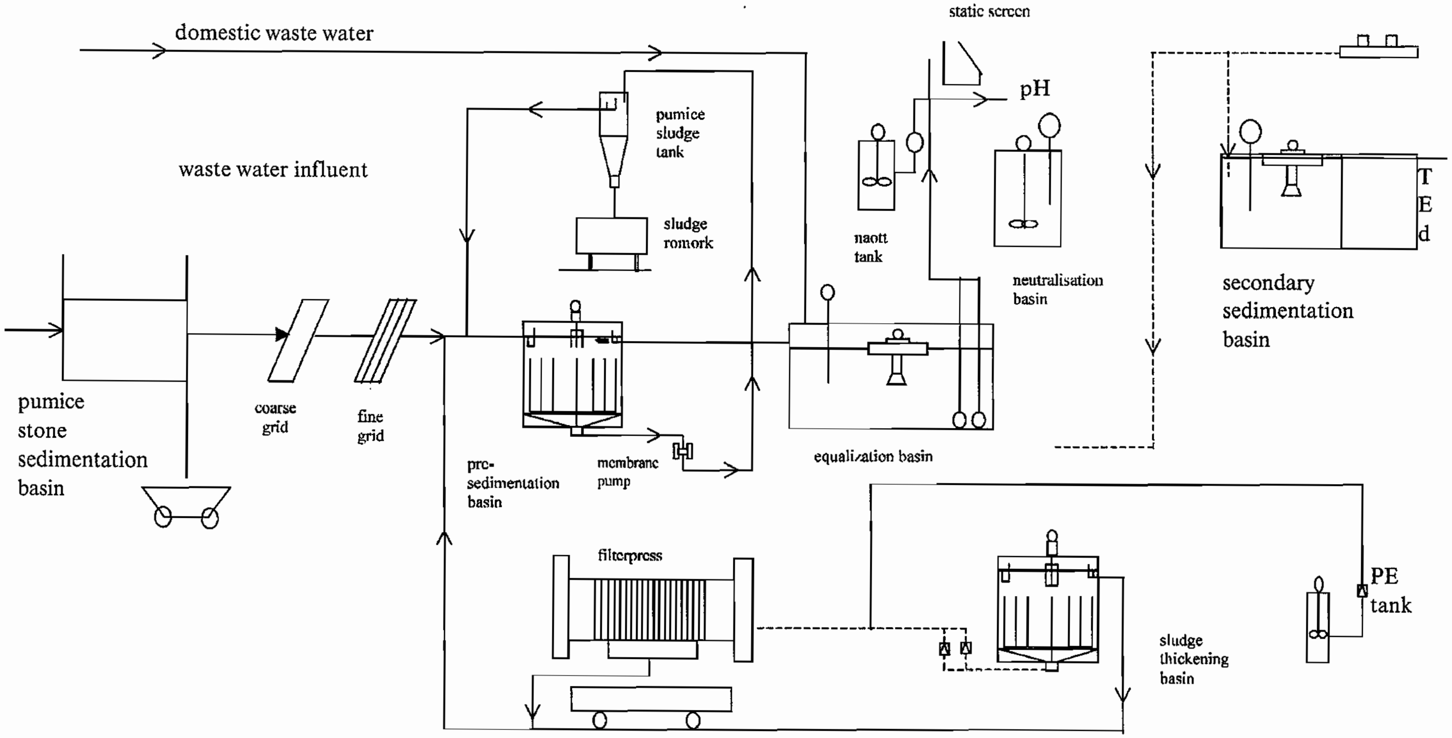

Fig. 6. Treatment plant flow sheet

The entrance of neutralisation basin, with a static screen, having 0.25 mm openings and cleaned by manual, holds finer solid matters such as fibers which can not be hold in pre-grid system. In neutralisation basin, required pH value and alkalinity of waste water for activated sludge system is adjusted by using automatic dosage system, dosing hydrated lime, working with a pH meter. There is a mechanical mixer for providing best mixing. The reason of lime usage is both to increase the pH value of waste water and to add alkalinity for providing nitrification.

Then waste water passes to the aeration basin providing about 88% COD removal with continue flow stirred squared type activated sludge process. Required oxygen and mixing are provided by two jet aerators taking command from submerged oxygen electrode to get start/stop between at 2-3.5 mg/l oxygen level. Hydraulic retention time of this basin is about 18 h, sludge age 20 days and organic loading is between 0.05-0.15 kg BOD_5/kg VSS-day. The best effluent obtained from daily precipitation of activated sludge is about 400 ml/l at 2500 mg VSS/l.

Then partly treated waste water passing to secondary sedimentation basin with rectangular shape is separated from activated sludge as treated. Large parts of activated sludge, precipitated at the bottom of this basin, are returned to aeration basin and excess of it is send by attraction to the sludge thickening basin. Treated water is flumed over secondary sedimentation basin as polished and discharged to the channel which is connected to adjacent creek called Sinan Dede which is one of the branch of Ergene river. Secondary sedimentation basin consists of a sludge scraper connected to a forward-back moving bridge. Sludge returning is provided by two submerged pumps assembled to moving bridge. Retention time is about 4.5 h, TSS load is < 145 kg MLSS.$m^{-2}d^{-1}$ and flume load is < 125 $m^3m^{-1}d^{-1}$. Sludge thickening basin has a mechanical mixer and scraper. Excess biological sludge is pumped from this basin to filter press by a piston type horizontal pump. Sludge, converted into cake form, is removed as solid waste at the Corlu municipality landfill.

While source based waste water samples have been collecting from the production processes, composite samples were also collected from the treatment plant both influent and effluent. Then they were analysed for evaluating the removal capacity of waste water plant. The results are outlined in Tables 8 and 9.

Table 8. Conventional characterization of waste water treatment plant

Processes	pH	COD	BOD_5	NH_3-N	TKN	T-P	TSS
				(mg/l)			
Influent	7	600	282	1.12	28.56	5.8	247
Effluent	7.1	74	30		11.76		47
Removal efficiency (%)		88	90	99	59		81

Table 9. Conventional characterisation of waste water treatment plant for re-use criteria

Processes	Colour (m^{-1})	TDS (mg/l)	Conductivitiy (µS/cm)	Alkalinity ($mgCaCO_3/l$)
Influent	43.3	910	1890	37
Effluent	3.5	602	1270	58.2
Removal efficiency (%)	92			

It is observed that influent characteristics of this treatment plant are in convenience with the literature values[1]. According to Water Pollution Control Regulation in Turkey, jean-washing industry is included in woven fabric finishing sub-category of textile industry in terms of discharge standards for receiving bodies. These discharge standard values and comparison of waste water effluent are outlined in Table 10.

Table 10. Comparison of treatment plant effluent with discharge standards in Turkey[8]

Parameters	Plant influent	Plant effluent	Removal efficiency (%)	Composite samples for 2 h
pH	7	7.1		6-9
COD (mg/l)	600	74	88	400
BOD_5 (mg/l)	282	30	90	90
TSS (mg/l)	247	47	81	140
NH_3-N	1.12	traces	100	5

As can be seen in Table 10, jean-washing and dyeing industry waste water could be treated at about 80-90% removal efficiency. At the same time, colour occurring from used direct dyes could be removed with 92% efficiency. Since BOD_5/COD ratio and C/N/P composition are estimated 0.5 and 100/4/1.9, respectively, it is observed that typical biological treatment efficiency mentioned in literature as 80-90% can be achievable in this treatment system. On the other hand, since all data were evaluated in terms of biological treatability, it can be said that jean-washing and dyeing industry's waste water can be treated in activated sludge system successfully and treatment plant effluent can also be reused without colour removal.

CONCLUSIONS

1. When stone washing process's place in the daily production and waste water generation are examined, it can be said that the highest value pollution based on COD is produced during this process. So, when a treatment plant will be designated for treating a jean-washing industry process waste water having stone washing process with production ratio of 70-80%, this point must be considered. Fur-

thermore, although the dilutions with the other process's of this waste water are concerned, the pH value of it should be expected approximately at 7.

2. Similarly, the highest pollution based on TSS is produced from bleaching washing process. When the other processes' TSS values are examined, if re-use alternatives will be applied on the processes, this process's waste water should be separated from the other streams and/or pre-treated for removing of high TSS concentration. If it is not made, it will cause an increase in TSS concentration in the total processes waste water.

3. 70 l waste water are produced per goods in stone and bleaching washing processes. This value decreases to 37 l, 23 l and 16 l in rinse-wash, silicone washing and tint dyeing processes, respectively.

4. Nitrogen load originated from tint dyeing process using direct dyes is 5 times higher than stone and bleaching washing processes.

5. When the measured values in conventional characterisation are evaluated in terms of re-use criteria mentioned in literature[6]:

- the conductivity values in all processes except for tint dyeing process are convenience with the literature;
- while stone washing and bleaching washing processes' waste water alkalinity is appropriate with the literature data, it is observed that the others are lower. But, it is thought that this situation will not be a problem for water usage in all processes except for dyeing process;
- TDS values in all processes, except for tint dyeing process, are in convenience with the literature data[1];
- pH values in all processes, except for rinse-wash and bleaching washing process, are not in convenience with the literature data and so, for these processes' waste water a treatment facility such as neutralisation is required;
- since COD and TSS values are higher that the literature data, they are subjected to a treatment in order to achieve the values.

6. The large amount of waste water generated by textile miles has a strong colour, which is a major problem for the receiving bodies, in addition to a high organic pollutant loads. One of the important tasks in plant control strategies for textile industry is to select raw materials and auxiliaries with less pollutant load in waste water without changing the quality of the product, the second being in recovery of waste water for re-using as process water in production. When mass balances are examined in all the processes, it is observed that used chemicals in these processes have not complex structures compared to other textile dyeing sub-categories. So, there will not exist problem for waste water re-use with removing colour.

7. When BOD_5/COD ratio and C/N/P composition are examined, it could be said that jean-washing and dyeing industry's waste water could be treated in activated sludge system successfully at about 80-90% removal efficiency.

8. There is no need in any complex tertiary treatment of treatment plant effluent except for TSS removal. Because, before reuse of it, TSS, resulted from with a majority bio-mass particulates which are harmful for human health, should be treated with only disinfecting system by using either chlorine or any oxidation chemicals.

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Received 19 October 2001
Revised 20 June 2002