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Effects of Caustic Recovery on Pollution and Cost of Production in a Cotton Textile Industry

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Abstract: Textile manufacturing industry is uses substantial amount of chemicals not only in the production processes but also in manufacturing the raw materials. Chemicals used in textile production are generally classified as commodity chemicals and speciality chemicals. Former are used in Bulk and the later are used in small quantities. Caustic Soda (Sodium Hydroxide) is one of the major chemicals which are used in large quantities for producing cotton textiles. Caustic soda results in highly alkaline waste water from the textile mills which makes the effluent toxic and poses difficulty in treatment of effluent. This study to assess the impact of caustic recovery from the mercerization plant was conducted in a cotton fabric manufacturing unit. A pilot scale single effect evaporator was used to concentrate the effluent stream from mercerization process and the changes in the quality of effluent and concentration of caustic lye were studied over a period of one year. In addition to the improvements in the quality of effluent, the study has also focussed on the cost savings in terms of effluent treatment and production due to reuse of the recovered caustic.

Keywords: Caustic soda, Chemicals, Costs, Effluent, recovery

I. INTRODUCTION

Textile production is highly chemical and water intensive industrial activity. According to estimates demand for chemicals is expected to grow substantially driven by the growing emphasis on product quality throughout the global textile industry, as well as wider consumer demand for comfortable and durable apparel [1]. The global demand for textile chemicals has witnessed

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an increase of 2.8 percent per year [2]. As per studies of material balance during the trials conducted in cotton yarn and cotton fabric units as part of this research, it is observed that the majority of the chemicals used in the textile production processes end up in the waste mostly in the effluent as there is very little and negligible consumptive use of these materials and chemicals. Caustic soda results in strong alkaline effluent rendering the waste water toxic and can lower the dissolved oxygen content of receiving waters, threaten aquatic life and damage general water quality downstream[3].

Caustic Soda (Sodium Hydroxide) is one of such material which is used in substantial quantities and also contributes to the pollution load in the effluent. This study focuses on the reuse aspects of caustic soda. Although caustic soda is used both in yarn and fabric manufacturing, it was found during the studies that the caustic soda used in the desizing and fiber cleaning process has substantial impurities and hence needs elaborate treatment arrangements before making it amenable for reuse in the process.

Mercerizing among all the processes consume maximum amount in cotton textile processing and the resultant waste stream is relatively free from impurities. For implementation of any pollution prevention technique, evaluation and pricing of clean technologies transfer is an area of major concern for small and medium scale industries.

Recoverability of the residual caustic soda is also dependent on residual concentration of caustic soda which is high in mercerizing effluent as compared to other processes [4]. Hence mercerizing process was selected for this study for recovery of caustic soda and its effects on pollution and cost of production. Typical process flow diagram of cotton fabric mercerizing without caustic recovery is shown in Figure 1.

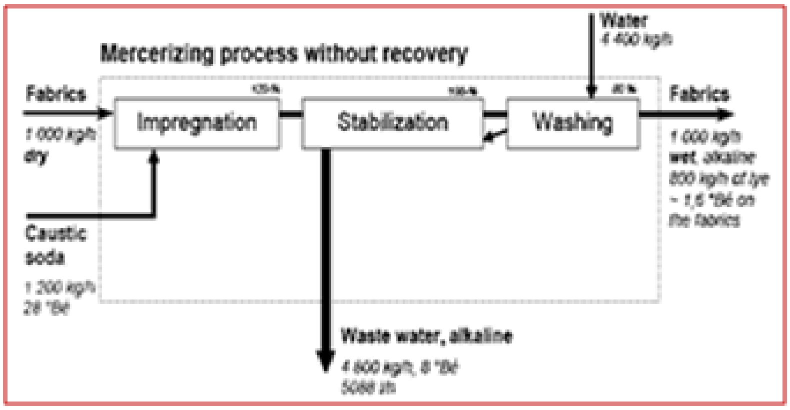

Figure 1: Typical Cotton Fabrics Mercerizing Process without Caustic Recovery

II. MATERIALS AND METHODS

A. Methodology for Caustic Recovery

It is observed from the process of manufacturing and waste water characterization studies conducted in a cotton fabric manufacturing industry that the effluent stream from the mercerization process contained highest concentration of caustic soda with least impurities whereas the streams from dyeing and finishing had relatively much lesser concentration of caustic soda and more impurities and colour which makes the process of recovery of caustic more complex, economically unviable and reuse impossible due to product quality considerations. The trials were, therefore, confined to the mercerization effluent stream for assessment of impacts.

Vacuum Evaporation is one of the most applied techniques adopted in the concentration of solutions. Evaporation is a process of phase transition of liquids to vapour phase below boiling point. Rising film vacuum evaporators comprise of long tubes enclosed in a cylindrical vessel. Liquid circulates by natural convection in tubes and steam is induced in the outer cylinder housing the tubes [5]. Concentrated liquid is recycled and condensate is discharged back for boiler feed. Vacuum have been used successfully by the Surface Finishing Industry for point source recovery of plating baths and rinse waters [6]. In this study, a locally fabricated single stage vacuum rising film vacuum evaporator was used for conducting the trials in the cotton fabric manufacturing industry. Segregated effluent from mercerizing process was circulated through the vertical tubes. Steam was injected in the outer shell.

During trials, the samples of effluent from the mercerization process was subjected to simple primary treatment of settling in hopper bottomed glass beakers and filtration through the filter papers for removal of lint, fluff and other particles. Concentration of caustic soda in the effluent was predetermined. Thereafter the filtered and decanted effluent was subjected for concentration in the single stage vacuum evaporator. Caustic soda concentration in the concentrated effluent was also determined to assess the increase in the caustic soda content. The concentrated caustic solution was used back to prepare the recipe of the same concentration required in the process of mercerization. The difference in the quantity of caustic soda used in original mercerization bath and the quantity of fresh caustic soda required to reconstitute the mercerization bath of similar strength by using concentrated spent lye is taken as the quantity of soda recovered.

B. Methodology for Assessment of Impact on Effluent Quality

For evaluation of impacts on quality of composite equalized effluent, the samples were collected and analyzed according to the procedures prescribed

[7] and the variation in BOD, COD, TSS and quantity of effluent in the equalized effluent were measured to assess the effect of recycling of the spent caustic lye. Composite sampling was preferred over the grab sampling in order to ensure that the samples were truly representative of the actual flow pattern of effluent from the processes duly accounting for the variations in the process and flow [8] [9]. For this purpose, 10 litres buckets were used and the quantity proportionate to the flow of effluent was taken. Flow was measured at every thirty minutes interval with stop watch and bucket fill method for a period of 10 hours as the complete process cycle in each plant is of about 8 to 10 hours. Thus twenty samples collected over a period of 10 hours were thoroughly mixed in proportion to the flow and homogeneous samples were prepared and analyzed as per standard procedure [10]. It is however worthwhile to mention that the procedures prescribed for analysis are identical to Standard Methods for the Examination of Water and Wastewater, 1995 in all other standards and manuals.

C. Methodology for Assessment of Impact on Cost of Production

There are two direct and tangible economic benefits due to recovery of caustic soda. First is in terms of savings because of cost of caustic soda recovered. Second is in terms of savings in the operating cost of the ETP due to quantitative reduction and qualitative improvement in the effluent. Quantitative values of caustic soda recovered in the Pilot Studies were determined. First the quantity of caustic soda required for preparing caustic lye in mercerizing without any use of recovered caustic soda was determined. Thereafter the spent caustic lye after concentration in the single stage vacuum evaporator was used to prepare mercerization recipe of required strength by adding fresh caustic soda. By subtracting the amount of fresh caustic soda required to reconstitute the mercerization bath of requisite strength by using spent lye from the total quantity required without caustic recovery, net quantity of caustic recovered is determined.

Reduction in the operational cost of ETP is another direct economic benefit. For quantifying the benefit in monetary terms, data for operating cost of Effluent Treatment Plants was collected and compiled for one year in which trials were conducted. This cost data was separately compiled for variable inputs such as coagulants, poly-electrolytes & other chemicals, power (for pumps & aeration systems) and sludge handling & disposal. These costs were determined in Rs/kl of effluent.

The reduction in pollution and quantity of effluent determined after isolating the mercerization stream was apportioned corresponding to the concerned variable cost parameter. For example reduction in BOD and COD was apportioned to the cost of power needed for aeration. Cost reduction due suspended solids was directly apportioned to consumption of ETP chemicals and sludge handling and disposal costs. Similarly cost reduction due to flow volume of effluent gives benefit in reducing the power cost due to pumping & aeration. Thus the total savings in the cost of operation & maintenance of ETPs is determined.

Major cost of infrastructure required for caustic recovery is due to vacuum evaporator. Operational cost is requirement of steam. As the multiple effect evaporators are available for customized requirement, the market cost was taken after enquiring from the suppliers in 2011. Cost of civil infrastructure is only in terms of mild steel framed structure which is estimated as per standard scheduled of rates [11]. Supply of steam can be given from the existing boiler and as such dedicated boiler is not required as part of infrastructure. However cost of steam generation has been considered while working out net savings. After determination of the total cost of infrastructure, the payback period for this pollution prevention option was determined.

III. RESULTS & DISCUSSIONS

It was observed that in the mercerisation process, cotton fabric is processed in a solution of concentrated caustic soda 28°*Bè* to 30°*Bè* (270 - 300 gm NaOH/l equivalent to 170 - 350 gm NaOH/kg textile substrate for about 40 - 50 seconds. Degree Baume (°*Bè*) is a measure of density of indicated on Baumé scale. The fabric is then rinsed in order to remove caustic soda. This rinsing water is called spent weak lye with concentration of 5°*Bè* to 8°*Bè* (30 - 50 gm NaOH/l). By vacuum evaporation, the concentration of weak lye can be increased to 25 - 40 °*Bè* (225 - 485 gm NaOH/l), depending on the mercerising process requirement and characteristics of spent lye. It was observed in the trials that in perble range mercerization maximum concentration of weak caustic lye could be achieved only up to 25 - 28 °*Bè*. In case of bleached fabric concentration up to 40 °*Bè* was also achieved.

During the study period and trials on the waste water characterization and quantification; the concentrations of caustic soda in the effluent from the mercerization process (spent lye) were found to be 56, 42, 61, 53 and 48 grams NaOH per litre respectively in the equivalent range of 6°*Bè* to 9°*Bè*. Figure 2 represents the values of caustic soda concentration observed in the mercerizing effluent stream.

Based on the trials, the maximum concentration of weak lye in the pilot single stage vacuum evaporator was observed to be 357 grams NaOH per litre equivalent to 33.4°*Bè*. Steam was induced in the system at an average rate of 4.5 kg per kg of water content evaporated to achieve maximum concentration of 33.4°*Bé*.

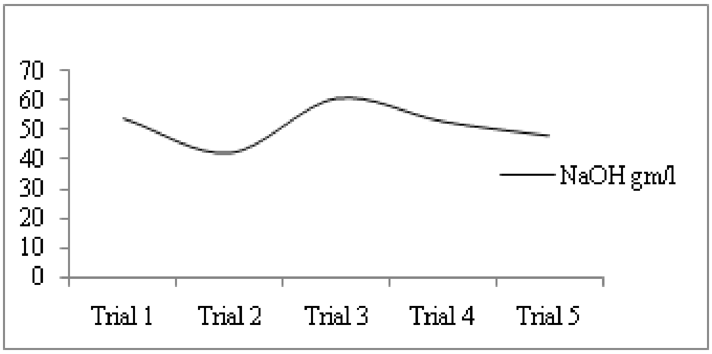

Figure 2: Observed Concentration of NaOH gm/l in Mercerizing Stream

A. Effect of Caustic Recovery on Pollution

Primary effect of recovery & recycling of caustic soda from the mercerizing effluent is in terms of reduction of pollution. Similarly due to recycling of the mercerizing effluent quantity of effluent is also likely to be reduced. The weak lye was isolated from the combined effluent stream and composite samples were collected and analysed for Colour, COD (Chemical Oxygen Demand), BOD (Bio-chemical Oxygen Demand) and TSS (Total Suspended Solids). Table 3.1 exhibits the values of these parameters.

Table 1: Values of Parameters before & after Caustic Recovery

Parameter		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
Colour (Pt-Cb Units)	Before CR*	3485	2980	3250	3195	3490	3280.00
	After CR*	2970	2555	2850	2745	2830	2790.00
COD	Before CR*	5462.65	7165.68	6784.18	6159.15	6928.32	6500.00
	After CR*	4962.68	4272.22	5044.15	5145.56	5045.43	4894.01
BOD	Before CR*	1022.52	938.56	997.85	817.62	1033.45	962.00
	After CR*	812.38	804.58	761.38	792.2	800.69	794.24
TSS	Before CR*	248.82	241.29	213.46	198.78	217.64	224.00
	After CR*	196.85	178.65	187.5	176.8	189.45	185.85
Eff in kl/ tonne of product	Before CR*	113.96	97.45	106.28	104.48	114.13	107.26
	After CR	87.44	96.13	88.93	96.47	95.06	92.80

*CR denotes Caustic Recovery

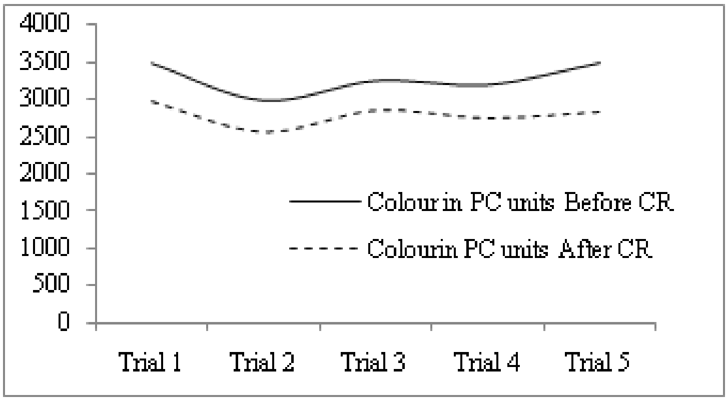

Figure 3: Observed Values of Colour before & after Caustic Recovery

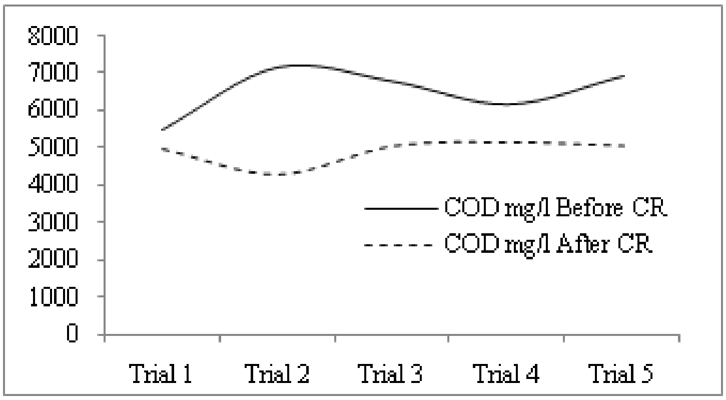

Figure 4: Observed Values of COD before & after Caustic Recovery

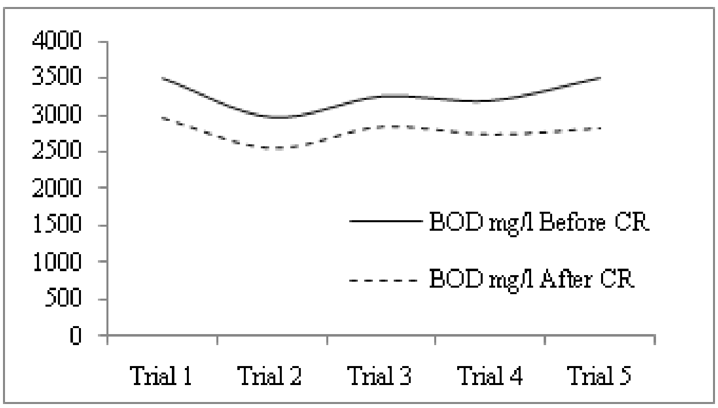

Figure 5: Observed Values of BOD before & after Caustic Recovery

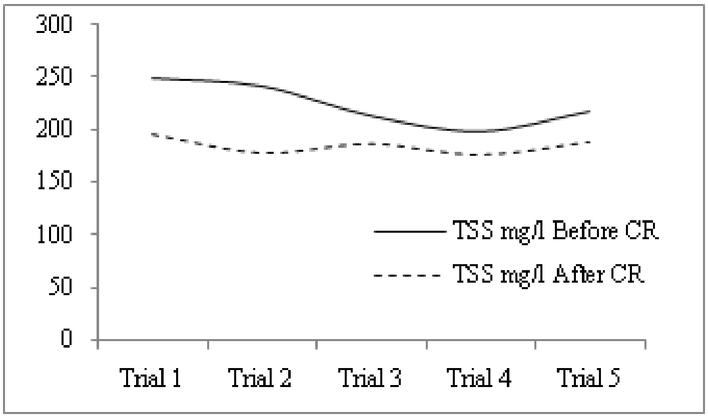

Figure 6: Observed Values of TSS before & after Caustic Recovery

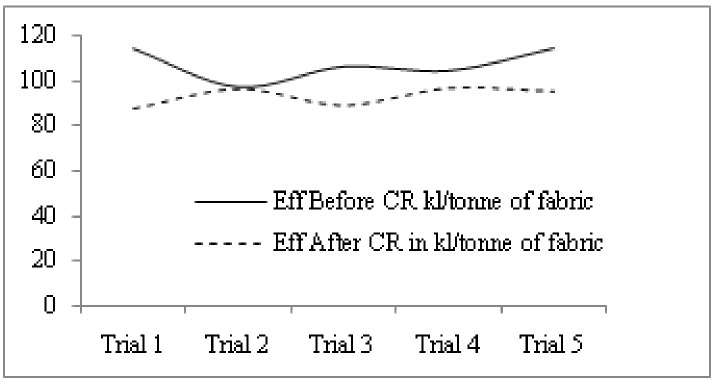

Figure 7: Observed Quantities of Effluent before & after Caustic Recovery

It is observed form the results given in Table 1 that reduction in COD was 24.68% as compared to the corresponding reduction in Colour, BOD, TSS and Effluent quantity as 14.93%, 17.45%, 17.03% and 13.56% respectively. Though there was considerable reduction found in the COD values, the reduction in Colour, BOD and TSS was only relatively less.

B. Effect of Caustic Recovery on Cost of Production

Caustic recovery system no doubt needs substantial capital investment besides recurring expenses in terms of power, steam & maintenance of the system. It is, therefore, imperative that the cost benefit issues of the proposition are properly addressed and adequately explained before any business decision to invest in the pollution prevention strategy is taken.

As the effluent (weak caustic lye) from the mercerising section is recycled and reused after concentration in the evaporator, this reduces the net consumption of caustic soda. In addition to this, there will also be corresponding reduction of effluent and pollution loads as discussed in preceding section 3.1. Cost of production, therefore, may correspondingly reduce in the following aspects:

- Reduced consumption of caustic soda used in the manufacturing process;
- Reduced ETP costs due to:
  - (i) Volumetric Reduction of effluent;
  - (ii) Reduced pollution load;
  - (iii) Reduced sludge quantities.

Table 2: Summary of Annual Cost Savings due to Caustic Recovery from Mercerizing Effluent.

Sr. No	Description	Caustic Soda	Eff Volume	Pollution Load Reduction				Total Savings	Total Cost without Reuse of weak lye effluent
				Colour	COD	BOD	SS		
1	Reduction %	11.72	13.56	14.93	24.68	17.45	17.03		
2	Cost Reduction Rs. in lakhs								
	A. In Production due to Caustic Soda	14.63	0.00	0.00				14.63	124.80
	B. In ETP:								
	i. Power	0.00	2.43	10.17				12.60	87.70
	ii. Chemicals	0.00	0.00	12.33				12.33	93.61
	iii. Sludge handling & disposal	0.00	0.00	3.00				3.00	17.57
3	Total Savings per annum	14.63	2.43	29.50				42.56	323.68
4	Annual O&M Cost of infrastructure for recycling							11.28	NA
5	Net Savings per annum							31.28	NA
6	Capital Cost of infrastructure for recycling							195.00	NA
7	Payback period in Years							6.23	NA

Summary of Cost savings because of Caustic Recovery is presented in Table 2. Costs are determined as per actual cost of input for caustic soda in terms of per unit weight of fabric. Actual cost of caustic soda at the time of study was Rs. 16 per kg (Year 2011). Cost of ETP inputs are also actual cost incurred in operation & maintenance of the ETPs in both the units compiled during the study.

Capital cost for recycling infrastructure include single stage evaporator; cost of alkali proof holding tanks, ultra-filtration for each spent caustic lye stream, special stainless steel plumbing fixtures and pumps to reuse the concentrated spent lye.

Operational cost of steam has been taken as Rs. 2 per kg (Year 2011) which was determined on the basis of bulk steam generation in the existing boilers. Savings in terms of cost of chemicals, power and sludge handling have been determined corresponding to the reduction in pollution levels due to concentration of weak lye & recovery of caustic soda.

IV. CONCLUSIONS

It is clear that the caustic recovery is a major pollution prevention alternative in the cotton textile industry. Results of the study indicate that overall pollution reduction in terms of COD may be achieved up to 24.68% and corresponding reduction in quantity of effluent achieved during study is 13.56%. This reduction in pollution load and effluent quantity results in annual savings in production cost up to Rs. 14.63 lakhs due to cost of recovered caustic and Rs. 27.93 lakhs in operation of ETP can be realized due to caustic recovery. Payback period for the investment required to create infrastructure is 6.23 years due to high capital cost of vacuum evaporator and high operational cost due to steam requirement. However in the long term perspective caustic recovery from the mercerizing effluent is one of the best possible alternatives for pollution prevention in cotton textile industry.

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