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Water and Wastewater Quantification in a Cotton Textile Industry

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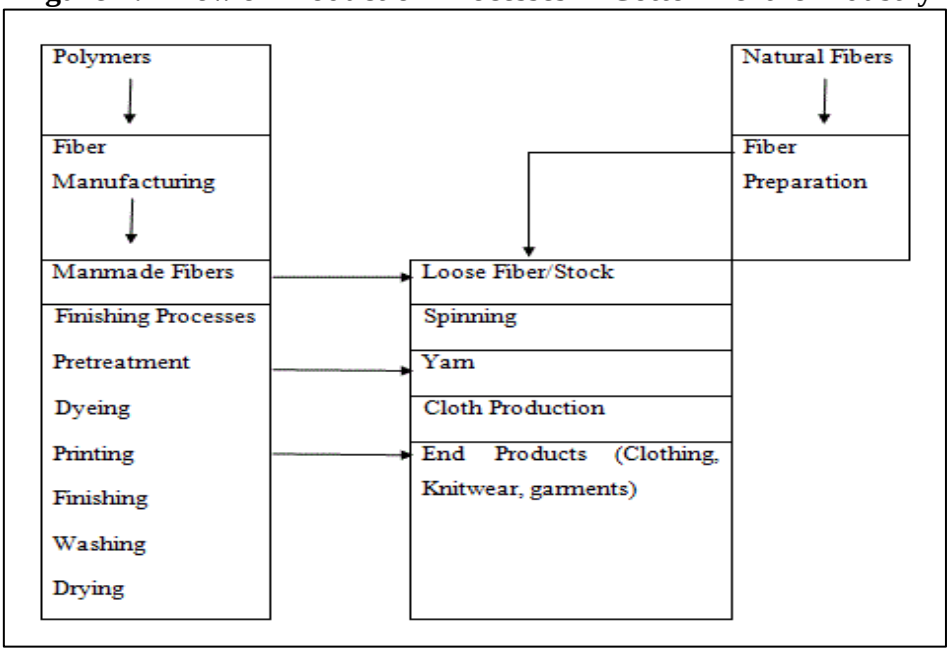
ABSTARCT- Textile manufacturing industry uses substantial amount of water not only in the production processes but also in manufacturing the raw materials. Water is used successively in almost every process of production. In textile manufacturing use of water is essentially in conjunction with several chemicals and the water used in numerous washing cycles of cotton fabric or yarn carry along these chemicals in the waste water. Consumptive use of water is a very small proportion of the total quantity of water used and most of the water is discharged in the form of wastewater. Similar is the fate of chemicals used in the manufacturing of textiles. Ingredients of chemicals used in textile production ultimately discharged as wastewater have considerable environmental significance and exert pollution load in the recipient water bodies where such effluents ultimately get disposed. This study aims at assessment of quantity of water consumed and wastewater discharged from every process of production in a cotton textile industry. Study has been conducted in an actual industrial set up over a period of one year. Primary data was collected during the study of each process operation for water consumption and wastewater discharged. Secondary data was collected from all the tube wells used for abstraction of water in the industry. Data of water consumption and wastewater in a cotton textile is an immensely useful benchmark in planning and prioritizing the pollution prevention and wastewater treatment strategies. Study also presents opportunity to the textile industry in general to plan conservation of water.

KEYWORDS: Textile, Water, Wastewater, Chemicals, Effluent, Pollution, Production Process.

1. INTRODUCTION

The textile industry carries out numerous processes ranging from the manufacture of cotton fibers and fabric production. The first step in the production of a cotton textile product is the preparation of cotton fibers for further processing. Cotton fibers are turned into yarn by spinning or texturing and preparation. Dyeing and finishing can be done on yarn or on woven fabric. The last step is the fabrication of a finished product. The preparation, dyeing and finishing of cotton textile products consume large amounts of energy, chemicals and water [1]. The wet-processing operations require the use of several chemical baths at high temperature to give the desired characteristics to the yam or fabric. According to the sequence of production; processes may be classified as: **(i) Pre-treatment; (ii) Dyeing and; (iii) Finishing.** Figure-1.1 depicts the sequence of production processes in a typical textile industry.

Figure-1.1 Flow of Production Processes in Cotton Textile Industry



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Depending upon the use of the water; the processes are classified as (**i) Wet; (ii) Intermediate and (iii) Dry**. Wet processes are those operations in textile manufacturing which consume water and most of the water used is discharged as wastewater. Intermediate processes use water but the incidence of waste water discharge is insignificant. Dry process operations neither consume water nor discharge any wastewater. The classification of textile manufacturing processes according to use of water is summarized in Table-1.1.

Table-1.1 Wet, Intermediate and Dry Processes [1]

WET	INTERMEDIATE	DRY
Scouring of wool	Sizing	Picking, carding and combing
Scouring of cotton	Felting (Non-woven fabrics)	Spinning
Desizing	Adhesive processes (including carpet backing)	Weaving
Bleaching	Functional finishing (e.g. flame retardancy, moth proofing etc)	Knitting
Mercerising	Printing	Tufting
Carbonising		Mechanical Finishing
Milling		Stentering
Dyeing		Heat setting
Washing		Singeing

According to United States Environmental Protection Agency [2], the textile production processes can usually be performed in batch, continuous or semi-continuous systems. In batch systems, the machine is loaded with a fixed amount of fabric, chemical solutions are added, and the process is conducted. After processing, the chemical bath is discharged and the fabric is washed. Subsequent processing is usually done in the same machine. In continuous systems, the chemical mix is placed in pans, and the fabric runs through the machine continuously for a predetermined period. Process wastewater is a major source of pollutants in Textile production [3]. It is reported [4] that widespread contamination of water may occur in rivers, drainage canals and coastal waters due to discharge from textile industry. Neşe Tüfekci *et al* [5] have reported that in practice, the amount of water used and wastewater discharged and level of pollutants from different industries vary considerably. One essential and often difficult step in water pollution prevention is to accurately and realistically assess the current status of industry and its potential for improvement. Schedule-VI (Part-B) of the Environment (Protection) Rules-1986 [6] states

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the wastewater generation as 120 m^3/tonne for nylon & polyester and 150 m^3/tonne for viscose rayon. No specific wastewater generation has been mentioned in the said Schedule-VI for cotton fiber/fabric production. Report on Accounting for Water, June, 2007 [7] by the Waterfalls Institute of Technology Transfer, New Delhi, states that the Principle of "Tragedy of Commons" is more relevant to the water as a commodity. As the water is held in common ownership by all hence there is a dire need for socially equitable and ecosystem based approach to water management.

2. MATERIALS & METHODS

Study was conducted in two cotton based textile industrial units. One of the units manufactures yarn and the second unit manufactures fabric. For the purpose of the study, these industries have been named as Unit-I and Unit-II. Production data of both the units was obtained from the registers maintained as per mandatory requirement of excise & sales tax. Both the units use groundwater to meet their requirements of water from the underground sources. The data of all the tube wells was collected and inventory of water sources was prepared. The quantitative data of all the water abstraction points was measured using the capacities of the storage reservoirs and daily yield of all the pumps in each industry. Monthly data of the total water abstracted from the ground water was prepared for one year. Concurrently the quantity of wastewater was measured at the inlet of the equalization tank of effluent treatment plant of each unit. On the basis of this realtime data, quantity of water consumption and effluent generation per tonne of the product is determined. Average values of the above items were also determined on the compiled data. Thus the specific water consumption and specific wastewater generation were then determined as a function of production expressed as m^3/tonne of yarn or fabric.

Simultaneously, water balance was also studied for each unit operation of the production process of fibre/yarn for one year. Random trials were conducted during different months and seasons of study period to account for variations in product profile and water consumption patterns. The studies were carried out for all types of products namely full white yarn, yarn dyed with vat dyes and yarn dyed with reactive dyes. Water input into each process was measured by assessing the flow rate by bucket-fill method using the stop watch. Flow rate was multiplied by the time for which the valves were kept open in the complete process cycle. Similarly the quantity of effluent being released from each process was also measured. Weighted Mean values according to the proportion of types of products for Water consumption and effluent generated from each process were

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determined as a function of production expressed as m^3/tonne of product. The proportion of each type of product was determined and was observed as 17% for full bleach white yarn, 2% for vat dyed yarn and 81% for reactive dyed yarn in Unit-I. The proportion of each type of product was observed as 37% for full white or yarn dyed fabric, 18% for vat dyed and 45% for reactive dyed fabric. Same methodology was adopted for determining the water balance of in both the units

Two values for water consumption and wastewater determined according to two independent methodologies are than compared for checking the extent of variation, precision and revalidation of the study results.

3. RESULTS & DISCUSSIONS

Details of total water abstraction from all sources were collected and effluents were measured at the inlet of ETP. Data of production of fiber and yarn in Unit-I was collected for the registers maintained by the management for purpose of excise & taxation. The results have been presented in Table-3.1

TABLE-3.1

Data of Annual Water Use and Effluent Discharged in Unit-I

(Based on Tube Wells Abstraction & Flow in ETP)

Month	**Production of Yarn (tonnes)**	**Water Consumed & Effluent Generated in m^3**		**Water & Effluent in m^3/Tonne of product**		**Effluent as % of Water Consumed**
		Use	**Waste**	**Use**	**Waste**	
Apr	525	85760	79213	135.91	125.54	92.37
May	544	88641	81257	133.09	122.01	91.67
Jun	542	78851	72595	136.89	126.03	92.07
Jul	503	67136	64756	122.73	118.38	96.45
Aug	487	73142	68236	129.45	120.77	93.29
Sep	**6755**	73770	65906	125.46	112.09	89.34
Oct	**563**	81540	74201	140.34	127.71	91.00
Nov	525	73992	70884	140.94	135.02	95.80
Dec	544	75866	71739	139.46	131.87	94.56
Jan	542	72699	66331	134.13	122.38	91.24

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Month	Production of Yarn (tonnes)	Water Consumed & Effluent Generated in m^3		Water & Effluent in m^3/Tonne of product		Effluent as % of Water Consumed
		Use	Waste	Use	Waste	
Feb	503	72375	66028	143.89	131.27	91.23
Mar	487	76736	72569	157.57	149.01	94.57
Total	**6755**	**920508**	**853715**	**NA**	**NA**	**92.80**
Average	**563**	**76709**	**71143**	**136.66**	**126.84**	**92.80**

The average values for water balance in respect of each process of the production observed during the trials are given in Table-3.2. The weighted average values shown in Table represent the values balanced according to the proportion of all types of products i.e. white, vat or reactive dyed yarn/fiber.

Table-3.2 Water Balance on the Basis of Process Study Trials in Unit-I

Sr. No.	Process	Operation	Water (m^3/tonne of fabric)							
			White		Vat Dyed		Reactive Dyed		Weighted Average	
			Use	Waste	Use	Waste	Use	Waste	Use	Waste
1.	Pre-treatment	Scouring & Bleaching	21.44	20.34	22.87	20.34	23.56	22.00	22.62	20.89
		H_2O_2 Neutralization	6.88	5.88	7.90	6.34	7.25	6.56	7.34	6.26
		Washing	0	0	21.34	21.34	20.64	17.88	20.99	19.61
2.	Dyeing	Dyeing	0	0	41.94	36.38	39.5	34.66	40.72	35.52
		Washing	0	0	15.76	14.68	13.42	11.82	14.59	13.25
3.	Finishing	Softening & Neutralization	15.40	12.34	25.92	23.34	22.78	18.69	21.37	18.12
Total			**43.72**	**38.56**	**135.73**	**122.42**	**127.15**	**111.61**	**127.63**	**113.65**

Similarly for Unit-II which manufactures cotton fabrics, the monthly details of production, water abstraction and effluent generation have been shown in Table-3.3

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Table-3.3 Data of Annual Water Use and Effluent Discharged in Unit-II

(Based on Tube Wells Abstraction & Flow in ETP)

Month	Production (Tonnes)	Water Consumed & Effluent Generated in m^3		Water & Effluent in m^3/Tonne of product		Effluent as % of Water Consumed
		Use	Waste	Use	Waste	
Apr	792.5	107730	102164	135.94	128.91	94.83
May	841.93	109750	106703	130.36	126.74	97.22
Jun	962.05	118590	116458	123.27	121.05	98.20
Jul	775.08	120033	109010	154.87	140.64	90.82
Aug	899.17	121604	117730	135.24	130.93	96.81
Sep	1005.61	124960	115783	124.26	111.50	92.66
Oct	1006.96	120030	115354	119.20	114.56	96.10
Nov	918.61	105610	102228	114.97	111.29	96.80
Dec	1127.01	121410	115064	107.73	102.10	94.77
Jan	1045.56	117670	112860	112.54	107.94	95.91
Feb	982.32	115913	111961	118.00	113.98	96.59
Mar	1007.15	138060	125933	137.08	115.11	91.22
Total	11363.95	1421360	1351248	125.08	118.91	95.07
Average	**947.00**	**118446.67**	**112604**	**125.08**	**118.91**	**95.07**

Corresponding values for water balance in respect of each process of the production observed during the trials are given in Table-3.4. The weighted average values shown in Table represent the values balanced according to the proportion of each type of product i.e. white, vat or reactive dyed fabric.

Table-3.4 Water Balance on the Basis of Process Study Trials in-II:

Sr. No.	Process	Operation	Water (m^3/Tonne of fabric)			
			White	Vat Dyes	Reactive Dyes	Weighted Average

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			Use	Waste	Use	Waste	Use	Waste	Use	Waste
1.	**Pre-treatment**	**Desizing & Bleaching**	12.35	10.54	14.34	12.56	11.94	9.89	12.88	11.00
		Mercerizing	27.64	24.32	31.54	25.76	29.84	27.42	26.38	27.85
		Washing	12.60	13.98	13.02	16.58	14.02	14.36	16.51	12.96
2.	**Dyeing**	**Perble Range**	0.00	0.00	14.26	10.68	13.55	9.12	11.53	9.42
		Pad Steam	0.00	0.00	11.86	9.26	10.58	8.56	11.22	8.91
		Washing	0.00	0.00	24.52	24.88	23.00	25.56	26.14	25.70
3.	**Finishing**	**Softening & Neutralization**	10.84	8.55	15.34	13.54	14.56	12.48	13.58	11.52
Total			63.42	57.39	124.88	113.26	117.49	107.39	118.24	107.36

Water balance studies conducted in Unit-I as per Table-3.1 show that the overall consumption of water during April, 2010 to March, 2011 was 920.51 million litres and the corresponding quantity of waste water was 853.72 million litres. Annual Average water consumption was observed 136.66 m^3/Tonne of the processed yarn/fibre whereas the resultant waste water was observed 126.84 m^3/Tonne of the processed yarn/fibre. Highest value for water consumption was observed as 157.57 m^3/Tonne and lowest value was observed as 122.73 m^3/Tonne. Corresponding highest and lowest values for waste water were observed as 149.01 kl/tonne and 118.38 m^3/Tonne respectively. It is seen that 92.80% of the water consumed is discharged as effluent as per month wise data. Water balance studies conducted in Unit-II as per Table-3.3 showed that the overall consumption of water during April, 2010 to March, 2011 was 1421.36 million litres and the corresponding quantity of waste water was 1351.25 million litres. Annual Average water consumption was observed 125.08 m^3 /tonne of the finished fabric whereas the resultant waste water was observed 118.91 m^3 /tonne of the finished fabric. Highest value for water consumption was observed as 154.87 m^3 /tonne and lowest value was observed as 107.73 m^3 /tonne. Corresponding highest and lowest values for waste water were observed as 140.64 m^3 /tonne and 102.10 m^3 /tonne respectively. It is seen that 95.07% of the water consumed is discharged as effluent as per month wise data.

Further trial studies of individual process operations were also conducted during the same period to correlate and compare the mean values with those obtained from the month wise data of water and waste water. The mean values as per Table-3.2 for water consumption and resultant effluent on the basis of trial studies in unit-I were observed as 127.63 m^3/Tonne of

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yarn/fibre and resultant value for effluent was observed as 113.66 m^3/Tonne of yarn/fibre. It is observed from the data of Table-3.2 that 89.05% of water consumed results in effluent. The mean values as per Table-3.4 for water consumption and resultant effluent on the basis of trial studies in unit-II were observed as 118.24 m^3 per tonne of fabric and resultant average value for effluent was observed as 107.36 m^3 per tonne of fabric. It is observed from the data of Table-3.4 that 92.02% of water consumed results in effluent. The water consumption and wastewater generation in Unit-I and Unit-II are figuratively represented in Figure-3.1 and Figure-3.2.

Figure-3.1 Actual & Average Monthly Water Consumption in Unit-I & II

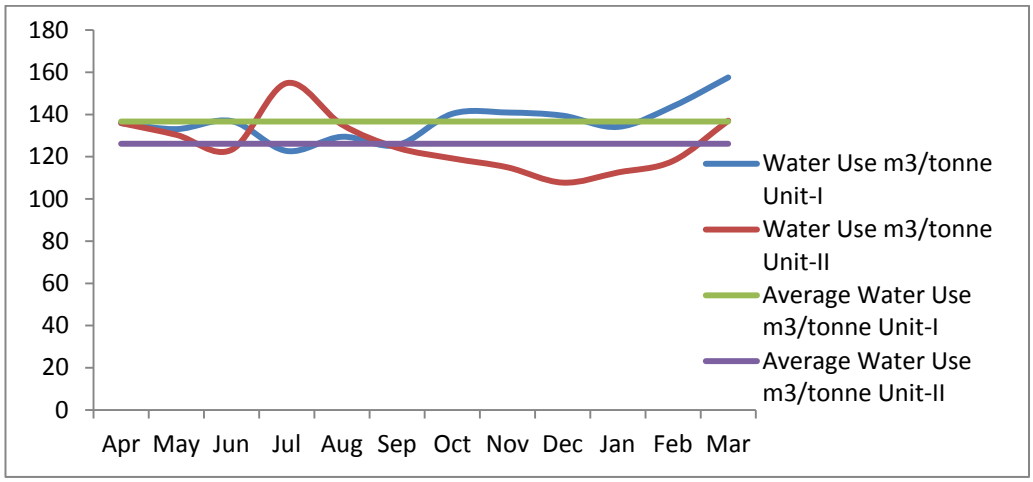
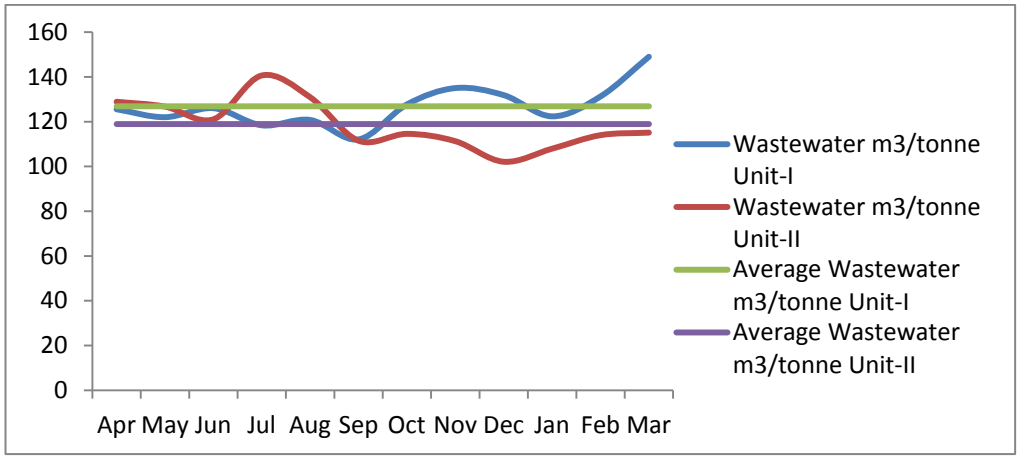


Figure-3.2 Actual & Average Monthly Wastewater Generation in Unit-I & II



According to the study trials, it is also observed that 40% water consumption is in pre treatment section, 43% in dyeing section and 17% in finishing section in Unit-I. Corresponding share of effluent contribution by these three sections of production in Unit-I is observed as 41%, 43% and 16% respectively. In Unit-II, 47% water consumption is observed

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in pre-treatment process, 41% in dyeing and 12% in finishing process. Proportion of wastewater generation form pre-treatment, dyeing and finishing processes has been observed as 48%, 41% and 11% respectively. According to studies by Aysegul PALA, July, 2001 [8] waste water is generated from mainly from three sources in cotton textile industry with average proportion as 45% from cotton pre-treatment, 35 to 40% from dyeing, and 5 to10% from finishing operations during full capacity operation. These values are comparable with those observed during the study of process. Processwise proportion in percentage terms for water consumption and generation of wastewater in both Unit-I and Unit-II is depicted in Figure-3.3 and Figure-3.4.

Figure-3.3 Processwise Percent Water Consumption in Unit-I & II

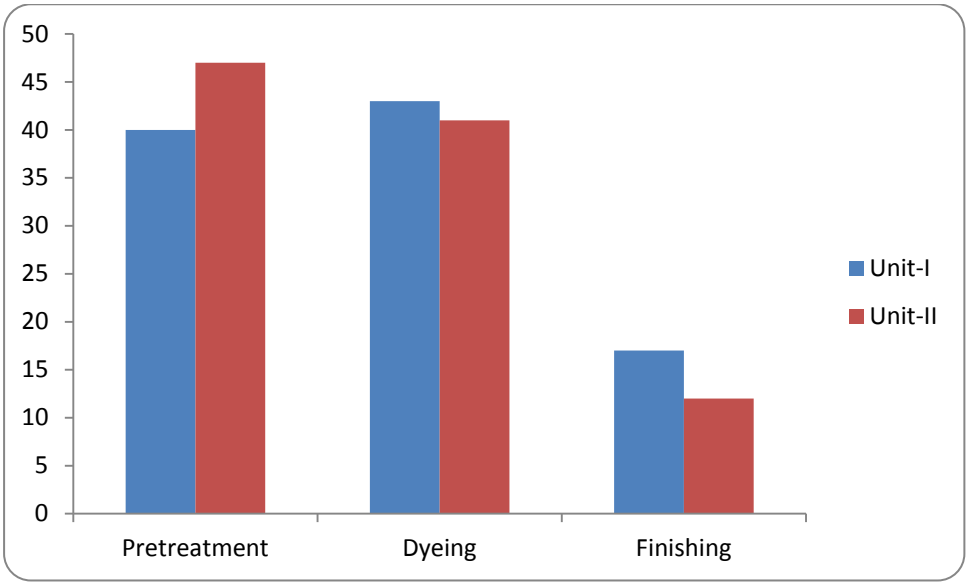

Figure-3.4 Processwise Percent Wastewater Generation in Unit-I & II

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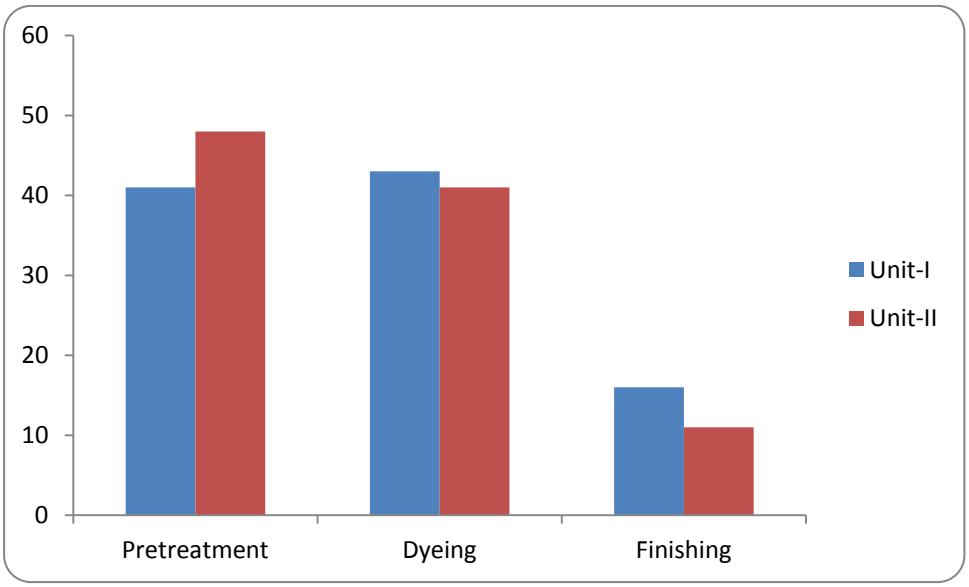

Variation is observed in assessment of water consumption and effluent generation determined on the basis of month wise data and process study trials. In Unit-I, the values determined according to month wise data are higher by 6.60% and 10.40% for water consumption and effluent generation respectively as per values in Table-3.1 and Table-3.2 respectively. In Unit-II values determined according to month wise data are higher by 5.47% and 9.71% for water consumption and effluent generation as per Tables-3.3 and Table-3.4 respectively.

Comparatively the consumption of water and generation of effluent as per month wise data is more in Unit-I than in Unit-II by a margin of 8.4% and 6.27% respectively. Similarly comparative water consumption and effluent generation determined as per study of process show that water use and effluent generation in Unit-I is more than Unit-II by a margin of 7.00% and 5.53% respectively. Overall variation between the effluent generation as a function of water consumption determined on the basis of the month wise data and actual process studies was observed as 3.75% for unit-I and 4.27% for Unit-II respectively. The comparative analysis based on secondary data and primary data determined on the basis of process study trials is depicted in Figure-3.5

FIGURE-3.5 Comparative Analysis of Water Balance of Unit-I&II

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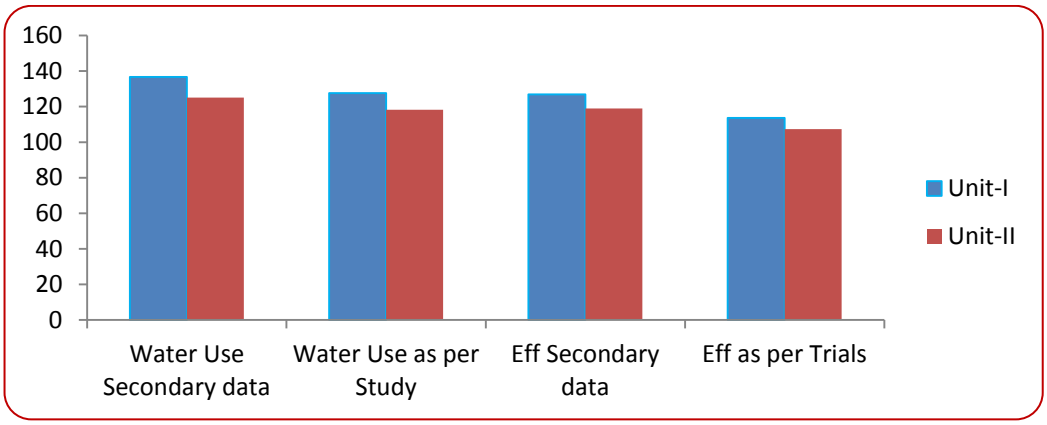

4. CONCLUSIONS

It is established from the study that mean values of water consumption determined by averaging the values of primary & secondary data for manufacturing of cotton yarn and cotton fabric have been assessed at 132.15 m^3/tonne and 121.66 m^3/tonne respectively. Corresponding values of wastewater generation have been observed as 120.25 m^3/tonne and 113.14 m^3/tonne. The consumption of water and generation of waste water are proportional to quantity of production. Scale of operation has direct link with the consumption of water and effluent generation. Specific water consumption and wastewater generation in small plants is likely to be higher than the larger plants. Pre-treatment and dyeing processes consume maximum water and hence result in maximum effluent. These processes account for 83% of water consumption and 84% of effluent in Unit-I and 88% of water consumption and 89% of effluent in Unit-II. It is concluded that the water consumption and effluent generation in m^3 per tonne of the product observed during the study trials is less than the quantities arrived at by analyzing the secondary data. This can be explained due to the fact that the study trials focussed on the process unit operations and did not account for waste generated from non-point sources such as water losses in distribution, floor washings and utilities. The process analysis of water consumption and waste water generation provides the baseline benchmarks for a comprehensive pollution prevention and water conservation in the cotton textile manufacturing.

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