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Environmental Protection with Economic Gain: A Win-Win Situation

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ABSTRACT

In the industrial sector, the financial gain is generally considered at the cost of environmental degradation. The environmental protection and economic benefit are common conflicting objectives in many optimization problems. In any multi-criteria problem, the most challenging part is to optimize the conflicting goals. But if these objectives become non-conflicting, then the problem can be solved with ease. This paper is all about minimizing the environmental impact of industrial processes while maximizing the net economic benefit. There is a general misconception of linking the environmental protection with a financial loss. This is not always true; the Eco-Efficiency or Cleaner Production Technology (CPT) is a perfect example to disprove this notion. Economics of CPT regarding water savings for the textile-processing sector in Pakistan has been analyzed in this paper. Changes in water use before and after the implementation of water conserving technologies in the textile sector of Pakistan from a study conducted by the Cleaner Production Institute (CPI) are utilized to perform a cost-benefit analysis. Direct financial benefits that could be achieved through the application of these technologies are presented only. Other environmental benefits, though not described here, are of no less importance. The study results reveal that very high potential of water savings exists for most of the investments on CPT.

KEYWORDS: ***Cleaner Production Technology (CPT); Cost-benefit; Environment; Textile Industry; Water Conservation.***

1. INTRODUCTION

Cleaner production technology (CPT) and eco-industrial development are becoming popular around the globe [1]. The developing countries with resource constraints are among the most benefitted nations by adopting eco-friendly approaches in their industrial setup. The same trend can be observed in the textile sector of Pakistan because of its potential of improving environmental performance without compromising the profit margin. The textile industry is the largest and the most important economic sector in Pakistan. To remain competitive in the national and international market, Pakistan textile industry needs to meet a new challenge— a paradigm shift: to internalize the environmental cost into its economic process [2]. Awareness about the environmental issues related to industrial pollution has grown over the past few decades. Industries, in general, are said to be contributing to environmental pollution all over the world. The textile industry is no exception. Since consumers have become more environmentally

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conscious, their demand for environmentally friendly products has increased. Also, the international trade organizations are giving a great deal of attention to trade-related environmental problems and are including the environmental aspects in their policy-making framework. As a result, the textile processing sector is facing a challenge of conforming not only to the national discharge standards (National Environmental Quality Standards) but also to the trade rules and buyers' demands in the national and international market. The industries' biggest concern, however, is the investment requirements both concerning capital and human resources to meet the environmental demand. CPT is a useful tool to attract the attention of the mill owners by giving an incentive of a direct financial return.

2. Cleaner Production Technology

The concept of pollutant reduction at its source has long emerged under the caption of *"Cleaner Production Technology."* In 1989, the United Nations Environment Program (UNEP) had first introduced the concept of Cleaner Production (CP). Before that, the effluent treatment or end-of-pipe (EOP) treatment was considered to be the only approach for pollutant reduction. Although CPT is considered a relatively new approach, it is based on a very primitive theme: "*prevention is better than cure,"* or prevent pollution rather than control it. The definition of CP for production processes by UNEP [3] is as follows:

"Cleaner Production results from one or a combination of conserving raw materials, water and energy; eliminating toxic and dangerous raw materials, and reducing the quantity and toxicity of all emissions and wastes at source during the production process."

2.1 Environmental and Economic Benefits of Cleaner Production

Cleaner production is generally considered an effective tool for sustainable development [4-9]. The numerous benefits are observed through the adoption of CPTs. Some of the benefits are improved working environment, reduction in resource consumption and waste generation, lower production cost, financial return through resource conservation, reduction in compliance cost through wastewater load reduction, improved production efficiency and product quality [10], development of continuous improvement capability within the production system [11], and better reputation as an environmental conscious industry in national and international markets [10]. Many studies, globally, have initiated to assess environmental and economic performances of the textile sector using various indicators and assessment tools such as resource reductions, savings, cost-benefit analysis, and statistical multi-criteria decision making [12-13].

2.2 Cleaner Technology Program (CTP) for Textile Processing Industries in Pakistan

The Cleaner Production Institute (CPI) in collaboration with the Royal Netherlands Embassy (RNE) and All Pakistan Textile Processing Mills Association (APTPMA) had initiated a Cleaner Technology Program (CTP) for textile processing industries in Pakistan. The overall duration of this project was three years (2004-2007). The objective of the project was to enable the Pakistan textile processing sector to meet the environmental challenges by complying with the national and international environmental standards through cost-effective, technically feasible, and locally available environmental solutions.

2.3 Pakistan Textile Processing Sector

Textile processing units in Pakistan are mostly concentrated in Karachi, Lahore, and Faisalabad regions. The textile industry in Pakistan, being the 8th largest exporter of textile products in Asia, plays a vital role in the country's economy. It contributes to 8.5 % of Gross Domestic Product (GDP), 63 % of the total export, 40 % of industrial labor force employment, and 46 % of the total manufacturing [14-15]. Textile processing, one of the three sub-sectors of textile industry placed after spinning and weaving sectors in the production, has the most substantial impact on the environment among other sectors. Textile processing includes bleaching, dyeing, printing, and finishing of fabric. Being a resource-intensive sector, textile processing sector uses an extensive amount of water, energy, and chemicals besides raw material used in cloth production. The inefficient use of these resources can pose a significant economic loss to the industry. Many researchers identified the role of cleaner production in the textile industry to ensure its sustainability through substantial resource savings through [16-19]. The following section discusses the use of water in the textile processing sectors of Karachi, Lahore, and Faisalabad. The current consumption levels and saving potentials of water are also investigated.

2.3.1 Water use in Pakistan Textile Industry

Textile processing usually is a water-intensive sector [20-21]. According to research titled "*Sustainable management practices to the textile industry for the growing economy"* by the World Wide Fund for Nature-Pakistan (WFF) UNDP, the textile industry uses more water than required [22]. Data collected by CPI for the selected textile processing units in Pakistan show the water consumption trend in the sector. Currently, an average amount of water used by the textile processing sector in Karachi is 64 liters per kilogram of cloth produced. For Lahore and Faisalabad, located in the Punjab province, these values are 188 l/kg and 174 l/kg respectively. The region wise variation is due to the difference in water pricing. In Punjab, more than 90% of the industrial units use groundwater [23]. Except for a tax on aquifer extraction and pumping cost, there is no other charge on groundwater.

Due to more consumption of water, the textile is one of the major industrial wastewater contributors in Pakistan [24]. According to a UNDP (United Nations Development Programme) report, wastewater generation from textile plants in Pakistan is three times more than from the plants with the same production in developed countries [25]. One of the significant environmental issues of the textile industry is linked to high water consumption in various processes such as scouring and dyeing [26]. Water reuse and recycling, on the other hand, are also becoming mandatory to fulfill the requirements posed by the Eco-labeling [27].

The water consumption levels in Pakistan textile sector may be reduced by using water conservation options. The measures which ensure optimum use of water in the textile processing sector also result in a decrease in water demand by the sector. The reduction in wastewater load is assumed to be equal to the quantity of water conserved.

3. MATERIALS AND METHODS

3.1 Cleaner Technologies in the Textile Sector Of Pakistan

This section discusses *Better Environmental Practices,* or Cleaner Production Technologies opted by the Pakistan textile processing sector. The economics of CPT options presented in this paper is based on data collected from the textile processing units located in Karachi, Lahore, and Faisalabad regions. This information is derived from the action plans prepared, respectively, for 15, 17, and 36 units in Karachi, Lahore, and Faisalabad regions.

The CPI has prepared a list of CPTs relevant to Pakistan textile processing mills. These options are designed for optimizing the typical processes in a textile processing unit. Table 1 presents a list of the selected CPTs. For this study, the selection criterion of CPTs is their potential for water conservation. The options which facilitate water conservation and for which direct financial benefits can be evaluated are discussed in this paper.

Table 1: Description of Selected Cleaner Production Technologies

ID	Description
A	Installation of Water Shut-Off Valves on Water Hoses
B	Installation of Water Flow Meters on Water Inlets
C	Reuse of Cooling Water
D	Reuse of Steam Condensate
E	Reuse of Clean Hot Water Stream of Jets
F	Recycling of Rinse Water at Rotary Printing Machine

Industry experts provided the estimates of water conservation according to their judgment and by consulting the relevant literature. The conservation estimates are presented in percent savings of the total water consumption. Based on these estimates, the financial investments (PKRs) and potential benefits (PKRs/yr) are calculated. The investments are one time fixed costs, whereas, the benefits are recurring and keep incurring annually. In the following sections, each CPT is defined for its intended purpose, the potential for water conservation, investment requirement, and associated benefits for each product group in all three regions (Karachi, Lahore, and Faisalabad). It should be noted that the selected CPTs are shortlisted from a long list of CPTs prepared by CPI by their water conservation potential.

Investments (PKRs-yr/ton of cloth production) are calculated by dividing the total cost of a given CPT option for all processing units where that option is to be implemented by the sum of the annual cloth productions in these units. Similarly, the benefits are also calculated and expressed in terms of rupees per ton of cloth production. The percent return on investment (ROI) is calculated for each CPT in the first year of implementation. The investments and benefits are not calculated when a specific CPT is not applicable or not suggested by the audit team in any unit of a specific product group (within the given sample size). A value of NA (not applicable) is used for such instances.

4. RESULTS AND DISCUSSIONS

4.1 Installation of Water Shut-Off Valves on Water Hoses

To control the unnecessary water wastage, the water shut-off valves were installed on water hoses. The water flows when the lever is pressed and stops flowing when it is released. Pretreatment, dyeing, and printing divisions use water hoses for their production processes and, therefore, are the potential locations for the installation of water shut-off valves. The estimated average water savings realized through the use of water shut-off valves during washing operations are 4 %, 3 %, and 3 % for Karachi, Lahore, and Faisalabad, respectively.

Annual benefits through the installation of water shut-off valves are calculated in terms of savings achieved through water conservation (Table 2). The unit cost of water (water plus pumping cost) is multiplied with the amount of water conserved to calculate the benefits. Water charges depend on the source of water from where it is acquired (through reverse osmosis (RO) or from other less expensive sources). At locations where water is virtually free (such as groundwater extraction), savings in pumping cost are used as benefits. Table 3 describes the investment needed by the textile processing sector to install water shut-off valves on water hoses.

ROI are calculated using investments and annual profits in the first year of installation. All prices listed here are 2007 values (1 PKRs. ~ 60US$).

Table 2: Annual Benefits from Water Shut-Off Valves on Water Hoses

Region	Number of Processing Units	Resource Conservation	Savings (m^3/yr)	Unit Cost (PKRs/m^3)	Annual Benefits (PKRs/yr)
Karachi	5	Water	56,855	32	**1,819,360**
Lahore	6	Water (Pumping cost only)	86,215	2	**172,431**
Faisalabad	20	Water (Pumping cost only)	352,625	2	**705,249**

Table 3: Investments and ROI for Water Shut-Off Valves on Water Hoses

Region	Annual Production (kg/yr)	Number of Shut-off Valves	Average Unit Cost (PKRs)	Investment (PKRs)	Benefits (PKRs/yr)	ROI (%)
Karachi	19,457,700	56	1,500	84,000	1,819,360	2,165
Lahore	12,201,841	92	1,500	138,000	172,431	125
Faisalabad	76,285,110	200	1,500	300,000	705,249	235

4.2 Installation of Water Flow Meters on Water Inlets

Optimal use of water may decrease the demands and unnecessary use of water, chemicals, and energy may be avoided. Water monitoring and record keeping are requisite to achieve this objective. Controlled use of water is only possible if water flow meters are installed on water inlets at all major water utility areas. Reduction in water use also reduces the end-of-pipe treatment cost by reducing the quantity of wastewater. The estimated average water savings are 4.25 %, 5 %, and 5 % for Karachi, Lahore, and Faisalabad, respectively. Water flow meters are needed in every production division.

The benefits are calculated in terms of monetary water savings (Table 4). The unit cost of water (water and pumping) is multiplied with the total annual water savings to get the annual monetary benefits. The investments shown in Table 5 are the cost of water flow meters and ball valves installed at various water utility areas.

Table 4: Annual Benefits from Water Flow Meters on Water Inlets

Region	Number of Processing Units	Resource Conservation	Savings (m^3/yr)	Unit Cost (PKRs/m^3)	Annual Benefits (PKRs/yr)
Karachi	11	Water	196,280	32	**6,280,960**
Lahore	16	Water (Pumping cost only)	462,084	2	**924,168**
Faisalabad	13	Water (Pumping cost only)	433,000	2	**866,000**

Table 5: Investments and ROI of Water Flow Meters on Water Inlets

Region	Annual Production (kg/yr)	Number of Flow Meters	Average Unit Cost (PKRs)	Investment (PKRs)	Benefits (PKRs/yr)	ROI (%)
Karachi	80,812,800	139	15,000	2,085,000	6,280,960	301
Lahore	53,460,203	129	14,000	1,806,000	924,168	51
Faisalabad	62,329,780	60	14,000	840,000	866,000	103

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4.3 Reuse of Cooling Water

Cooling water streams from singing machines, jet dyeing machines, compressor, thermal oil boiler pump, and ammonia chiller are usually discharged as wastewater. It is clean, warm water that can be collected and reused. This water can safely be used for washing purposes. If cooling water is collected and reused in all production divisions, then the estimated average reductions in total water consumption would be 3.25 %, 8 %, and 4.7 % for Karachi, Lahore, and Faisalabad, respectively.

Table 6 gives the annual benefits for textile processing units through the reuse of cooling water. Benefits are in terms of monetary water savings (water and pumping). The investment for storing and reusing of cooling water includes costs of storage tanks, pumps, pipes, ball valves, and collection pits (Table 7).

Table 6: Benefits from Reuse of Cooling Water

Region	Number of Processing Units	Resource Conservation	Savings (m^3/yr)	Unit Cost (Rs/m^3)	Annual Benefits (PKRs/yr)
Karachi	1	Water	9,000	32	**288,000**
Lahore	5	Water (Pumping cost only)	162,710	2	**325,420**
Faisalabad	30	Water (Pumping cost only)	781,900	2	**1,563,800**

Table 7: Investments and ROI of Reuse of Cooling Water

Region	Annual Production (kg/yr)	Investment (PKRs)	Benefits (PKRs/yr)	ROI (%)
Karachi	4,389,000	50,000	288,000	576
Lahore	11,476,310	265,000	325,420	123
Faisalabad	123,396,125	1,711,500	1,563,800	91

4.4 Reuse of Steam Condensate

In a textile processing, unit steam is also used as a source of energy. A part of this steam is recoverable when it gets condensed. Steam condensate is a distilled hot water stream that can be reused at other processes. The common practice in textile mills is to waste this condensate due to lack of proper collection and reuse arrangement. A proper collection may enable the reuse of this steam condensate for preparation of dye bath, preparation of printing paste, and as boiler feed water and hot water in the process vessels. Reuse of steam condensate not only conserves water and energy but saves chemicals when used in pretreatment, dyeing, printing, finishing, and as boiler feed water. The estimated average water savings are 5.25 %, 1.75 %, and 2.3 % for Karachi, Lahore, and Faisalabad, respectively.

The annual benefits are calculated in terms of water savings (Table). The hardware requirements for condensate collection may consist of the storage tank, pipelines, centrifugal pump, and ball valves depending on the actual situation. The cost of hardware is the investment requirement (Table 11).

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Table 10: Benefits from Reuse of Steam Condensate

Region	Number of Processing Units	Resource Conservation	Savings (m^3/yr)	Unit Cost (PKRs/m^3)	Annual Benefits (PKRs/yr)
Karachi	11	Water	34,210	32	**1,094,720**
Lahore	9	Water (Pumping cost only)	62,563	2	**125,125**
Faisalabad	15	Water (Pumping cost only)	174,430	2	**348,861**

Table 11: Investments and ROI of Reuse of Steam Condensate

Region	Annual Production (kg/yr)	Investment (PKRs)	Benefits (PKRs/yr)	ROI (%)
Karachi	18,388,800	180,000	1,094,720	608
Lahore	19,127,044	610,000	125,125	20.5
Faisalabad	39,579,745	1,070,000	348,861	32

4.5 Reuse of Clean Hot Water Stream of Jets

Presently a substantial amount of clean hot wastewater streams, generated from indirect cooling of jets, is wasted each day from textile processing units. These are clean streams at a temperature of 60-70ºC. A considerable amount of thermal energy can be recovered from these streams if this water is collected and reused. It can be used in jets or pretreatment and dyeing processes.

Reuse of clean hot water stream of jets not only decreases the use of water but saves energy. The average water savings are estimated to be 17 %, 2.4 %, and 2.8 % for Karachi, Lahore, and Faisalabad, respectively. The monetary benefits are calculated for the quantity of water conserved by adopting this option Table 12. Investments are the costs of hardware (storage tank, centrifugal pump, pipeline, collection pit, and ball valves) required for this purpose (Table 13).

Table 12: Benefits of Reuse of Clean Hot Water Stream of Jets

Region	Number of Processing Units	Resource Conservation	Savings (m^3/yr)	Unit Cost (PKRs/m^3)	Annual Benefits (PKRs/yr)
Karachi	2	Water	70,310	32	**2,249,920**
Lahore	4	Water (Pumping cost only)	38,211	2	**76,422**
Faisalabad	1	Water (Pumping cost only)	12,905	2	**25,810**

Table 13: Investments and ROI of Reuse of Clean Hot Water Stream of Jets

Region	Annual Production (kg/yr)	Investment (PKRs)	Benefits (PKRs/yr)	ROI (%)
Karachi	10,389,000	100,000	2,249,920	2,250
Lahore	9,976,310	225,000	76,422	34
Faisalabad	2,453,760	55,000	25,810	47

4.6 Recycling of Rinse Water at Rotary Printing Machine

Drain water from a rotary printing machine can be reused for other purposes. After chemical treatment, this water can be utilized for squeegees and drums cleaning and thus minimizing the use of fresh water for this purpose. An average reduction in water consumption through this option in Karachi is estimated to be 0.6 %. This option was not applicable to Lahore and Faisalabad textile processing sectors.

The investments required for this option are the costs of piping systems, storage tanks, and other equipment. Chemical treatment area and a dozing station are also needed for this purpose. The benefits are savings from conserved water. Benefits and investment associated with recycling of rinse water at rotary printing machine are presented in Table 14 and Table 15, respectively.

Table 14: Benefits from Recycling of Rinse Water at Rotary Printing Machine

Region	Number of Processing Units	Resource Conservation	Savings (m^3/yr)	Unit Cost (PKRs/m^3)	Annual Benefits (PKRs/yr)
Karachi	1	Water	1,269	32	**40,608**

Table 15: Investments and ROI of Recycling of Rinse Water at Rotary Printing Machine

Region	Annual Production (kg/yr)	Investment (PKRs)	Benefits (PKRs/yr)	ROI (%)
Karachi	7,083,000	600,000	40,608	6.5

5. CONCLUSIONS

The objective of this paper was to explore the potential of Cleaner Production Technology (CPT) as an economic tool for the textile processing sector in Pakistan. Industrial pollution is one of the major concerns among other environmental issues in many industrialized countries. Pollution generated from textile operations through conventional production processes poses significant environmental costs. CPT has been proved to be a strategic tool for sustainable production. This is a systematic approach to bring about continuous improvement in a management system. Apart from a good public reputation as an environmentally conscious industry, there is an economic benefit in the adoption of CPT. Any program that saves business money is more likely to succeed. Through an effective CPT program, an industry may achieve a high level of economic and environmental efficiency. CPT not only ensures an economic benefit through resource conservation but also reduces the load at the end-of-pipe (EOP) treatment. It reduces the consumption of raw material that results in a reduction of waste generation. The analysis presented in this paper reveals 6.5 % to 2,250 % ROI through implementing water conserving cleaner technologies in the textile processing units of Pakistan in the first year of implementation. During this analysis, the need for more comprehensive data monitoring was realized. The areas which require such attention are identified for further improvements in the analysis. These findings would help to develop a better data monitoring tool for the future validation of the results presented in this paper. At this point, it may be safely stated that through the adoption of cleaner technologies in the Pakistan textile processing sector, environmentally sound and economically feasible solutions can be guaranteed.

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