USAID
FROM THE AMERICAN PEOPLE

U.S.-Pakistan
Centers for Advanced Studies in Water

Eco-Innovation in Textile Processing Industry of KITE for Sustainable Product Processing

Final Report 2019



Principal Investigator:

Dr. Zubair Ahmed, U.S.-Pakistan Center for Advanced Studies in Water, Mehran University of Engineering and Technology, Jamshoro, Pakistan

MEHRAN UNIVERSITY
of Engineering & Technology
Jamshoro, Sindh, Pakistan

THE UNIVERSITY OF UTAH

Citation

Ahmed, Z.. (2019). Eco-Innovation in textile processing industry of KITE for sustainable product processing. U.S.-Pakistan Center for Advanced Studies in Water (USPCAS-W), MUET, Jamshoro, Pakistan

Author

1. Dr. Zubair Ahmed, U.S.-Pakistan Center for Advanced Studies in Water, Mehran University of Engineering and Technology, Jamshoro, Pakistan

ISBN

978-969-7970-13-1

Acknowledgment

This work was made possible by the support of the United States Government and the American people through the United States Agency for International Development (USAID).

Disclaimer

The contents of the report are the sole responsibility of the author and do not necessarily reflect the views of the funding agency and the institutions they work for.

U.S.-Pakistan
Centers for Advanced Studies in Water

Eco-Innovation in Textile Processing Industry of KITE for Sustainable Product Processing

Final Report 2019



Principal Investigator:

Dr. Zubair Ahmed, U.S.-Pakistan Center for Advanced Studies in Water, Mehran University of Engineering and Technology, Jamshoro, Pakistan

MEHRAN UNIVERSITY
of Engineering & Technology
Jamshoro, Sindh, Pakistan

THE UNIVERSITY OF UTAH

Contributors

Principal Investigator

Dr. Zubair Ahmed
Professor USPCAS-W, Mehran University of Engineering and Technology (MUET), Jamshoro, Pakistan

Team Members

- ☐ Dr. Rasool Bux Mahar, Professor, USPCAS-W, MUET, Jamshoro, Pakistan
- ☐ Dr. Tanveer Ahmed, Assistant Professor, USPCAS-W, MUET, Jamshoro, Pakistan
- ☐ Dr. Awais Khatri, Associate Professor, MUET, Jamshoro, Pakistan
- ☐ Dr. Sara Hassan, Assistant Professor, USPCAS-W, MUET, Jamshoro, Pakistan
- ☐ Dr. Arjumand Zaidi, Assistant Professor, USPCAS-W, MUET, Jamshoro, Pakistan
- ☐ Ms. Uzma Imran, Assistant Professor, USPCAS-W, MUET, Jamshoro, Pakistan
- ☐ Mr. Shan Saleem, Research Associate, USPCAS-W, MUET, Jamshoro, Pakistan
- ☐ Mr. Raffae Vistro, Research Associate, USPCAS-W, MUET, Jamshoro, Pakistan
- ☐ Mr. Bahadur Ali, Research Assistant, USPCAS-W, MUET, Jamshoro, Pakistan
- ☐ Ms. Aqsa Channa, MS student, USPCAS-W, MUET, Jamshoro, Pakistan
- ☐ Mr. Zeeshan Mazahir, Textile Expert, KITE, Karachi, Pakistan
- ☐ Mr. Ayaz Ahmed, NEC Consultancy, Karachi, Pakistan
- ☐ Ms. Tahira Zafar, GIS Mapping Expert, Karachi, Pakistan
- ☐ Ms. Sumera Zafar , GIS Mapping Expert, Karachi, Pakistan

TABLE OF CONTENTS

i

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

AnAMBR	Anaerobic-Aerobic Membrane Bioreactor
APTMA	All Pakistan Textile Mills Association
BOD	Biochemical Oxygen Demand
BOD_f	Biochemical Oxygen Demand Filtered
CEO	Chief Executive Officer
CETP	Combined Effluent Treatment Plant
COD	Chemical Oxygen Demand
DEM	Digital Elevation Model
DfE	Design-for-the-Environment
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
ECO	Electrocoagulation/Oxidation
EMP	Environmental Management Plan
EU	European Union
FGD	Focus Group Discussion
FPCCI	Federation of Pakistan Chambers of Commerce and Industry
GPS	Global Positioning System
GW	Groundwater
H_2O_2	Hydrogen Peroxide
HRT	Hydraulic Retention Time
ISO	International Organization for Standardization
KATI	Korangi Association of Trade and Industry
kg	Kilogram
KITE	Korangi Industrial Trading Estate
KWSB	Karachi Water and Sewerage Board
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
MBR	Membrane Bioreactor
MUET	Mehran University of Engineering and Technology
NGO	Non-Governmental Organization

NEQS	National Environmental Quality Standards
OLR	Organic Loading Rate
PI	Principal Investigator
Q_e	Effluent Flowrate
Q_i	Influent Flowrate
Q_r	Return Sludge Flowrate
SAAM	Sequential Anaerobic/Anoxic and Aerobic Membrane Bioreactor
SEPA	Sindh Environmental Protection Agency
SME	Small-to-Medium Enterprise
SRT	Solids Retention Time
SRTM	Shuttle Radar Topographic Mission
SWC	Sindh Water Commission
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USPCAS-W	U.S.-Pakistan Center for Advanced Studies in Water
UV	Ultraviolet
VSS	Volatile Suspended Solids
WHRB	Waste Heat Recovery Boiler
ZDHC	Zero Discharge of Hazardous Chemicals

ACKNOWLEDGMENTS

We sincerely express our thankfulness to the Almighty Allah, who gave us the potential to complete this project.

The author humbly expresses gratitude to all the contributors to the project. Sincere gratitude is extended to Dr. Bakhshal Lashari, Project Director, USPCAS-W, and Dr. Rasool Bux Mahar, Deputy Project Director (Academic and Research), for their kind guidance. The administration team of USPCAS-W has left no stone unturned to help the project team. The author presents thanks and appreciation to all of them, particularly to Mr. Syed Mansoor Ali Shah, Finance and Grants Manager; Dr. Kazi Suleman Memon, Manager Research; Mr. Muzafar Ali Joyo, Graphic Designer/Data Entry Operator; and Mr. Faizan, Logistic Officer.

The project team would like to aknowledge continuous support from the leadership of the Korangi Association of Trade and Industry (KATI) to allow us to hold focus group meetings at premises of their office and for kind guidance. Our special gratitude is for Mr. Muslim Mohamadi, Vice President Federation of Pakistan Chambers of Commerce & Industry (FPCCI), and Mr. Waseem Vohra, Chairman Standing Committee Academia-Industry Collaboration on Water Resources, FPCCI for their sincere guidance. We also pay our sincere regards to Mr. Hafiz Kashif, Director of Operations at Artistic Milliners- 02, and Mr. Zeeshan Mazahir, Group Manager at Artistic Fabric and Garment Industries for their corporation throughout the project and valuable input as an industry expert. We want to thank Mr. Junaid Ahmed Kori, Mr. Barkatullah, and Mr. Asif Jokhio for their help in the project.

This research work was not possible without the funding from USAID and technical assistance from the University of Utah, USA. In the last, the project team is sincerely thankful to Dr. Aslam Chaudhry, Party Chief, University of Utah, and Prof. Dr. Steven Burian, Project Director of USPCAS-W at the University of Utah.

EXECUTIVE SUMMARY

The textile processing units in Karachi generate polluted effluent, which is being discharged untreated or partially treated into the Arabian Sea. The environmental problems due to textile processing need to be addressed by adopting an innovative sustainable approach that prevents environmental damages and enhances economic gains. This study was conducted to explore and introduce eco-innovation options in the textile sector in Korangi Industrial Trading Estate (KITE), Karachi, to suggest technological improvements, better management practices, and end-of-pipe treatment, and to promote the culture of sustainable production and consumption in the textile sector.

The objectives of the study were to (i) examine the status of existing environmental measures in selected textile processing units, (ii) identify eco-innovation options suitable for different kinds of textile industries, and (iii) evaluate the ecological damage prevention under different implementation scenarios of selected eco-innovation options. The study was conducted in three phases. In phase I, surveys of and interviews from industries, seminars and focus group discussions (FGDs) were conducted. In phase II, environmental auditing of selected industries and identification of eco-innovation options by introducing system and subsystem level changes and component additions were done. Lastly, in phase III, evaluation of ecological damage prevention by the adoption of eco-innovation options using lifecycle impact assessment was carried out along with proposing a suitable site for a combined effluent treatment plant and developing environmental management plans for the textile processing industries.

During the survey and interviews, it was found that there were 149 textile processing units in the KITE region, of which 51 were wet-processing while 98 were dry-processing units. The wet-processing textile industries were divided into four categories, namely, denim washing (n=7), denim dyeing (n=9), apparel/home textiles (n=20) manufacturing, and towel manufacturing (n=15). Two seminars and four FGDs were organized, which were attended by government officials, industrial representatives, academia (faculty and students), members of the civil society and media persons. The building of academia-industry linkage was emphasized upon on every occasion. The current environmental conditions in different industrial areas in Karachi were highlighted, mitigation and remedial measures were suggested, and future pathways and framework were discussed.

During the evaluation of ecological damage prevention assessment, it was found that eco-innovation options in the denim dyeing industry, if adopted, could reduce the marine eutrophication by 70.03% compared to the current scenario, whereas, the reduction in marine eutrophication could be reduced by 50% and 99% in the denim washing and

apparel/home textiles industries, respectively. The largest impact reduction was found in the marine eutrophication category in the three types of industries. However, in the towel manufacturing industry, the largest impact reduction was estimated in the climate change category (the only other category being water resource depletion) by 91%. The wastewater generation by incorporating eco-innovation options was estimated to be reduced from 70,962 m^3/d to 28,385 m^3/d, whereas values of COD, BOD, and TSS in effluent from 1,862 to 101 mg/l, 587 to 25 mg/l and 630 to 17 mg/l, respectively. Suitable sites, (i) north of the industrial sector and (ii) west of the industrial sector, for a combined effluent treatment plant were determined through a weighted overlay analysis.

Conclusively, the environmental problems and their solutions were categorized into three key areas, i.e., water supply and distribution, environmental degradation and implementation of eco-innovation options, and a combined effluent treatment plant. A committee comprising of all the stakeholders was proposed to be formed to assist industrialists in adopting eco-innovation practices and providing a future framework for better operations and management. The successful implementation of the suggested eco-innovation options and the environmental management plan will not only benefit the ecology of Karachi and the Arabian Sea but also save costs for the industries and make their products' global competitiveness. The output of this study will serve as a guideline to promote eco-innovation within the textile sector of Pakistan and KITE, leading to sustainable production and consumption culture in textile processing industries.

1. INTRODUCTION

1.1 Background of the Project

Karachi's wastewater production accounts for 26% of the total wastewater production in Pakistan, most of which is generated from the industrial processes. It is predicted that only about 16% of the wastewater generated is treated while the remaining portion is discharged untreated into the Arabian Sea. Korangi Industrial Trading Estate (KITE) is one of the largest industrial estates in Pakistan, located in the district East of Karachi, covering a total area of about 34.4 km^2, and having more than 2,000 industrial units (Mehmood *et al*., 1998). Textile and leather are two dominant industrial clusters in KITE. Due to the area occupied and the usage of a high quantity of water in their processing, textile units are ranked highest amongst the industrial sectors for discharging pollutants in the environment (PAK EPA, 2005). However, the industrial effluent is not properly treated by the Karachi Water and Sewerage Board (KWSB) (Sahoutara, 2017). In a nascent groundwater study conducted in KITE and Korangi areas, flora and fauna have been categorized as heavily contaminate zones (Saleem, 2002; Rahman and Sabir, 2015). To address the situation, the leather industry has taken the initiative to establish a combined effluent treatment plant (CETP) with a capacity of treating 42,000 cubic meters of wastewater per day. This initiative of the leather tanning industry can be a major contribution to the reduction of pollution at the source (PTA, 2017).

The textile processing industry in Pakistan is facing challenges from its regional competitors for product costs, as well as the enhancement of environmental and sustainable processing. Even after these hindrances, the textile sector is flourishing at a good pace. Textile industries were granted with reduced tariffs under the European Union's (EU) Generalized System of Preference (GSP) status in 2013-14. This reduction in taxes has bolstered the exports of Pakistani products in European countries. Meanwhile, the textile sector is concerned about making their products more environmentally friendly and sustainable (Memon, 2013). The cleaner production program, in collaboration with the Cleaner Production Institute, has been implemented by the All Pakistan Textile Mills Association (APTMA). Recently, 29 units of textile processing mills underwent environmental auditing for their facilities. It was found that several of them were complying with cleaner production options in addition to end-of-pipe treatment plants. Moreover, many industries have adopted environmental management plans (EMPs) inclusive of ISO 14000 (Cleaner Production Institute, 2002).

Nevertheless, the Environmental Management Plans (EMPs) are mostly being applied to the production system, thereby leaving the possibility of achieving ecological damage prevention very low. In keeping with the global pressure for sustainable development and preservation of natural resources, the textile sector must take more robust steps towards the economic utilization of resources. There is a need of sub-system and system-level changes for production as well as component-based changes (e.g., treatment plants) to increase the value of their products by making the manufacturing process more environmentally friendly, while not compromising on the cost of products. These steps will help the textile sector to become more competitive in the global market.

1.2 Project Rationale

The project focused on the promotion of eco-innovation in the textile processing industry in Korangi, Karachi. Eco-innovation is defined as "*the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its lifecycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives*" (Kemp and Pearson, 2007). It is also defined as "*the creation or implementation of new, or significantly improved products (goods and services), processes, marketing methods organizational structures and institutional arrangements which - with or without intent - lead to environmental improvements compared to relevant alternatives*" (OECD, 2010).

There is a contrast between cleaner production and eco-innovation due to the scope of the two pathways. Clean production employs technological changes in addition to process improvements within the processing industry, while eco-innovation develops the vision of ideas to value creation-based production. Eco-innovation applies an integrated approach inclusive of technology improvements, organization innovations, institutional framework reforms, and strategies in the market. Sustainable production is closely linked with the idea of eco-innovation (Rashid *et al*., 2014).

1.2.1 Eco-innovation as a driving force for sustainable production

Eco-innovation and sustainable production are closely linked. For example, pollution control can be connected to products and processes modifications; and cleaner production interventions are tied directly to the redesign of products and production techniques. A conceptual linkage between sustainable production and eco-innovation is given in Fig. 1.1.

1.2.2 Eco-innovation dimensions

Innovation can be considered as a sequence of the complex chemistry of supply and demand. The systemic evolution of innovation can be grouped into three main dimensions; design issues, use/service perspectives, and governance (Carrillo-Hermosilla *et al*., 2009).

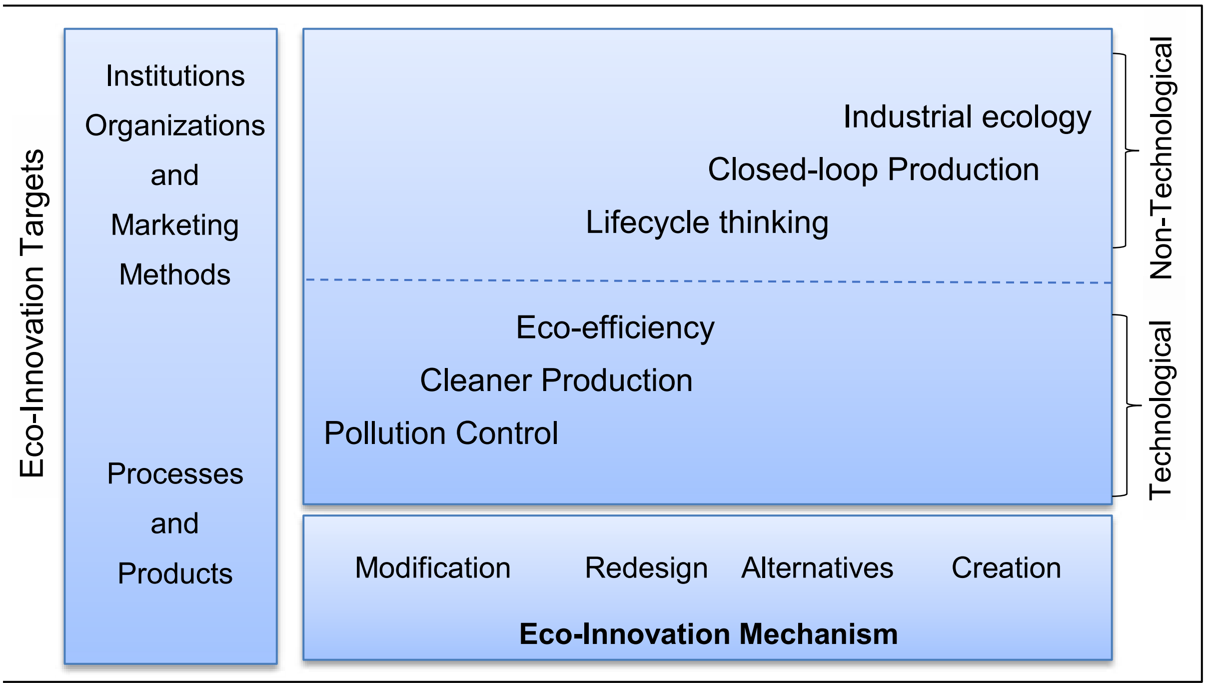

Fig. 1.1: Conceptual linkage of sustainable production and eco-innovation (OECD, 2010)

1.2.2.1 Design issues

Eco-innovation can be initiated at an early stage of the design of product and process development. The use of raw material, equipment, energy inputs, and source can be selected at this step of the design of the product. These elements of design can be readjusted by the need for elimination or reduction of any associated negative impacts which will be associated with them throughout the product lifecycle. This trend of incorporation of environmental impact concerns at an early design stage was becoming popular worldwide and termed in the literature as design-for-the-environment (DfE) or eco-design (Carrillo-Hermosilla *et al*., 2009). For the ecological interventions in the design stage, two different approaches can be followed: (i) human interventions, which are generally of adverse environmental impacts, and (ii) human interventions, which are considered as design failures. Environmental management can be focused on the re-design of human responses and processes with positive societal and ecological impacts. This structure indicates that the re-design of a process, together with radical changes, can bring the optimum sustainable product.

1.2.2.2 Component addition

This dimension focuses on the reduction and correction of adverse environmental impacts by adding a new component to the system without modifying the existing production process. Such component addition brings an additional cost to production.

End-of-pipe treatment is used to reduce the harmful environmental effects of processing and conveyance systems of goods, such as wastewater treatment plant and air quality control equipment (Carrillo-Hermosilla *et al*., 2009).

1.2.2.3 Subsystem change

Subsystem change aims to improve human-made systems to improve environmental performance. The primary objective is to eliminate adverse impacts by making better products and services while consuming fewer resources and generating fewer wastes. This approach is termed as eco-efficiency and based on the idea of producing low-cost products and services while imparting fewer impacts on ecological systems (Carrillo-Hermosilla *et al*., 2009).

1.2.2.4 System change

It deals with a radical shift in a system and its components. Subsystems are designed considering all possible environmental impacts of the developed system. In this regard, an attempt is made to integrate principles of natural ecosystems into industrial systems. The primary objective of a system change is to shift from the open-loop systems, where resource moves through the system and ultimately becomes waste, to closed-loop systems, where scraps serve as inputs for other production systems (Carrillo-Hermosilla *et al*., 2009).

1.2.2.5 User dimensions

It is defined as the competence of industries to engage their product users in designing their products by utilizing the creativeness of the users. After all, the users are the people who are the primary stakeholders and users of the product. Therefore, users can make innovative suggestions to improve and develop new products (von Hippel, 1988). Besides, the concept of eco-labelling is getting popular and different countries are implementing trade business barriers for less environmentally friendly products. The concept of eco-innovation can be used as a business strategy, and producing textile products with fewer impacts, consequently, can enhance the exports.

1.2.2.6 Product service dimensions

The driving force of innovation is mainly the benefits the innovator gained through change by increasing financial competitiveness and improvements in sustainability. The process of value addition in the services can have a crucial role in the innovation processes and environmental recovery (Stahel and Jackson, 1993). Innovation must incorporate higher value and reduce costs. Consequently, the existing customers can use the product more regularly, and new customers can be attracted, hence, increasing revenue generation. Through the adoption of eco-innovation, textile industries in KITE will have a comparative advantage of increased exports.

1.2.2.7 Governance dimension

Due to barriers to the prevailing systems' status quo, the creation of an innovative system and its diffusion cannot be quickly done because existing systems usually hinder or resist any new system as an alternative. 'Business as usual' is always preferred to avoid any unknown risks associated with innovation. This is also true for eco-innovation, mainly, if system-level changes are targeted (Carrillo-Hermosilla *et al*., 2009). The hindrance to new or innovative methods can even come from national security, government subsidies, and incentives or outright ownership, consequently, putting a substantial barrier to eco-innovation systems. To overcome such situations, governmental interventions are required to foster eco-innovations. In other words, environmental governance interventions are needed to promote eco-innovation. Such legislative responses can be in the form of a regulation defining the resources use, exclusion of any unauthorized users, distribution of benefits, cost recovery mechanism, monitoring requirements, enforcement system, and procedure for conflict resolution (Paavola, 2007). The government may put challenges over the management of a company to establish a relationship with the government and other stakeholders. Therefore, the administration must explore a more significant scope of business in society.

This study was conducted to promote eco-innovations within the textile industrial sector of Korangi (KITE). A review of production-technologies-associated environmental impacts and mitigation measures, innovative environmental technologies, and the need and scope of end-of-pipe treatment in selected textile processing industries in KITE are conducted in this study. The study does not include user/product service and governance dimensions. The focus of this research is on enabling the KITE textile processing industries to become cost- as well as environmentally competitive. The overall beneficiary for the promotion of eco-innovations within the textile industries of Pakistan will be textile processing units' operators, end-users of textile products, and the ecological system of Pakistan. The output of this study will serve as a blueprint to promote eco-innovation within the textile sector of Pakistan and KITE, leading to sustainable production and consumption culture in textile processing industries.

1.3 Objectives

The overall goal of the proposed research was to initiate eco-innovation activities within textile processing mills in the KITE area. It was carried out through the following specific objectives.

1. Examination of the status of existing environmental measures in selected textile processing units (Environmental Audit).

2. Identification of eco-innovation options suitable for the chosen industries by component addition, system changes, and subsystem changes.
3. Evaluation of environmental damage prevention according to different scenario-implementations of selected eco-innovation options.

2. MATERIALS AND METHODS

The investigation in this study was divided into three phases. Phase I started from the meetings with members of the Federation Pakistan Chamber of Commerce and Industry (FPCCI) committee and CEOs of the industries. The objectives of these meetings were to develop questionnaires and to select the industries for environmental auditing. The organization of seminars was also brought under discussions during these meetings. In Phase II, facilities were selected from the shortlisted industries for environmental auditing and review of their existing environmental management plans. During Phase III, the lifecycle assessment of the designated industries was conducted for ecological damage assessment and selection of best implementation scenarios. Furthermore, a suitable site was determined for a combined effluent treatment plant. In the last, environmental management plans were formulated for the selected scenarios. The three phases of the study are mentioned in Table 2.1.

Table 2.1: The phases of the project and associated tasks

Phase	Activities	
I	a.	Meetings with the FPCCI committees/CEOs of industries
	b.	Survey and interviews
	c.	Organization of eco-innovation seminars
II	a.	Environmental audits and review of existing environmental management plans (EMPs).
	i.	Suggestions for system and sub-system changes
	ii.	Identification of component addition options
III	a.	Life Cycle Assessment (LCA)
	i.	Assessment of ecological damage prevention
	a.	Selection of different implementation scenarios
	b.	Development of EMPs for selected scenarios
	c.	Site selection for a combined effluent treatment plant (CETP)

2.1 Meetings with the FPCCI Committee and CEOs of Industries

The project started with a meeting with the FPCCI standing committee for academia and water resources and industrial CEOs on July 15, 2018, at the FPCCI headquarters, Karachi. The main stakeholders of the meeting were the members of the FPCCI standing committee for academia and water resources and the project team, comprising of the principal investigator, environmental expert, textile expert, technical expert, and research associates. The standing committee of the FPCCI was briefed on the notion of eco-innovation in the textile industry. The committee ensured their cooperation and support to the project team, as well as guaranteed to bring government and industrial bodies for future meetings and seminars. Subsequently, an executive seminar on eco-innovation was organized on August 15, 2018, at the Pearl Continental Hotel, Karachi, in which eco-innovation and methodology of this research study were discussed with the members of the FPCCI standing committee on environment, and the associates of Korangi Association of Trade and Industry (KATI). The distribution of the participants invited to the seminar was as follows: industrial managers (n=20), federal and provincial policymakers (n=15), civil society activists and media persons (n=10), academicians, and researchers (n=15), and international wastewater management experts (n=5). The objectives and goals of the study were defined in these meetings.

2.1.1 Surveys and interviews

The collection of ground control points (latitude and longitude) using the global positioning system (GPS) of all the textile industries in the KITE area was done. A five-day field survey of the textile industries in the KITE was conducted to ground-truth the list of textile industries and identify any missing or new textile industries in the industrial area. The survey also included interviews where questions were asked from the concerned personnel about the type of industry, water consumption, and wastewater generation. A detailed questionnaire (Annex-1) was designed, and the industries were selected for the auditing based on the survey.

2.1.2 Eco-innovation seminars

The project team engaged the FPCCI and KATI and organized seminars and focused group discussions on eco-innovation-related improvement in the textile sector and to further elaborate the aims and objectives of the project to be executed at a selective progressive textile processing industry in KITE as a target case study. A survey strategy and survey protocols were developed in collaboration with the focused group. Moreover, APTMA was also involved in organizing the seminar.

2.1.3 Focus group discussions (FGDs)

Throughout the project, four focus group discussions (FGD) were organized. The dates and venues of the FDGs are mentioned in Table 2.2. In the FGDs, experts related to the textile industries were invited through the platform of KATI and FPCCI. Both the stakeholders enthusiastically invited the industrial personnel, and also provided a meeting place for the discussions.

Table 2.2: List of focus group discussions (FGDs) organized under the project

S. No.	Date	Venue	City
1	27/12/2018	Korangi Association of Trade & Industry (KATI), Korangi	Karachi
2	3/5/2019	Zafan Hotels	Karachi
3	27/6/2019	Head office, FPCCI, Clifton	Karachi
4	21/7/2019	Denim Dyeing Industry, KITE	Karachi
		Denim Garment Industry, KITE	

2.2 Phase I

2.2.1 Environmental auditing and identification of eco-innovation options

The examination of the existing environmental measures in selected textile processing industries was carried out for the environmental audit. Moreover, a review of the existing environmental management plans was also done, followed by the identification of component addition options and system and subsystem changes to improve environmental compliance and performance. The industries selected for the environment audits and reviewing of existing environment management plan were categorized into five categories: (i) apparel/home, (ii) denim dyeing, (iii) denim washing, and (iv) towel dyeing industries. A single facility for each type of industry was surveyed. These industries may not differ in terms of textile processes, e.g. pretreatment, dyeing, printing, washing and finishing, but may differ in the raw material inputs and their processing, and manufactured goods, e.g. woven raw/processed fabric of wider/ short width (case of home textiles, apparel and towel) or plied yarns (case of denim industry). Hence, the intensity of the produced waste load (water, emissions) from various processes in different types of industries varies depending on the resource inputs (chemicals, energy) and process sequences.

Following the semi-structured interviews of experienced managers, focused group members, and textile experts to understand the existing level of environmental preservation activities, another questionnaire (Annex-2) was developed. The questionnaire was shared with different types of major textile processing units to gather feedback on existing practices at processing facilities involved in water use efficiency and waste load minimization. Furthermore, the industries, which responded with filled questionnaires, were requested to allow for an environmental examination of their facilities to validate the provided information in the questionnaire and to seek further possibilities for system and sub-system changes, process improvement, and approaching higher levels of eco-innovation.

During the environmental examination, the ongoing processes were analyzed and assessed to identify the environmental measures already in practice and further possibilities of recommendations and doable modifications towards minimizing the waste load and resource conservation. Besides a detailed audit of all input streams/utilities, the focus was on the water in terms of its consumption, recycling, and reuse, produced wastewater load, and end-of-pipe treatment. One team each was formulated for the component addition identification and subsystem changes.

2.3 Phase II

2.3.1 Life cycle assessment (LCA)

Life cycle assessment is an analytical tool used to enumerate the environmental liabilities of a product or process throughout its lifecycle from the cradle to the grave. Product or process lifecycle entails all life stages of a product/process, i.e., the extraction of raw materials, production, transportation, use, and disposal of the product. ISO standardized LCA methodology, as reported in Vázquez-Rowe *et al*. (2012), was used to evaluate the environmental burdens. This methodology comprises four phases: (i) goal and scope definition phase, (ii) lifecycle inventory phase, (iii) lifecycle impact assessment phase and (iv) interpretation of the results phase.

2.3.1.1 Goal and scope of the impact assessment through LCA

The purpose of this activity is to define the boundaries of the system before performing an LCA. There are three types of system boundaries in an LCA, i.e., cradle-to-grave, cradle-to-gate, and gate-to-gate, of which one can be selected. The functional unit of the product is decided based on all the calculations and analyses conducted during the study.

2.3.1.2 Lifecycle assessment method

The impact assessment method, ILCD 2011+ midpoint, was used to study ten environmental impact categories. The impacts are categorized for midpoint impacts, i.e., climate change, ozone depletion, particulate matter, freshwater eutrophication, marine eutrophication, and water, mineral, fossil, and renewable resources depletion.

The four types of textile industries: denim dyeing, denim washing, towel dyeing, and apparel/home textile manufacturing industries, were selected to perform the LCA. These four industries come under the water-intensive category of textile industries. Other industries are almost the derivatives of these industries due to similar operations. The gate-to-gate LCA was carried out during the study to quantify the environmental impacts caused by these industries. Different implementation scenarios were generated for each category, and the data were processed through user-friendly software SimaPro (8.0). The assessment of ecological damage prevention from each generated scenario has been illustrated in the next chapter.

2.3.1.3 Lifecycle inventory

This study estimates the environmental impacts and deterioration caused by the activities involved in the dyeing of cotton. The functional units (basic unit of product used to quantify the impacts) was set as a meter of yarn-dyed. The data related to input and output were collected from the industry, hands-on measurement, and the literature. Only water-related environmental damages were assessed.

2.3.1.4 Selection of different implementation scenarios and ecological damage assessment

Two different implementation scenarios were generated for the assessment of ecological damage prevention. These generated scenarios were compared with the current scenario of the industry.

Current scenario

This scenario represents the current position of the industries towards environmental issues; most of the textile industries were being operated without the facility of a wastewater treatment plant; hence, no water reclamation. Besides, other measures to prevent air and soil pollution were not being practiced.

50% Implementation Scenario

In this scenario, ecological damage assessment was carried out by assuming 50% implementation of subsystem changes and component addition options that are explained in Section 2.2.1 and given in Section 3.3.

100% Implementation Scenario

This is a scenario wherein the assessment of the ecological damage prevention was done, assuming 100% implementation of the environmental management practices (Section 2.2.1. and 3.3.). Hundred percent implementation was made equal to the environmentally friendly practices already in place in selected textile industries from where the data were collected.

Several assumptions were made during the process modeling, such as the lake water of Pakistan was taken as a freshwater source as it was available in a database of SimaPro. The data inventory related to inputs, outputs, and emissions to water is shown in Table 2.3.

Table 2.3: Input and outputs data collected for LCA

Description	Unit
Inputs	
Yarn used	m/day
Freshwater consumed	gallons/ day
Electricity consumed	kwh
Outputs	
Yarn-dyed	m/day
Wastewater generated	gallons/day
Emissions to water bodies	
Chemical oxygen demand (COD)	g/day
Total phosphorus	g/day
Total nitrogen	g/day
Emissions to air	
Methane emitted	g/day

2.3.1.5 Estimation for wastewater generation

The total wastewater generation was calculated by measuring the area of all the water-intensive textile industries. Wastewater flowrate for each type of production was enquired from the industries, which was then divided by their respective areas. The ratio of flow to the area was measured for each category. For instance, out of the nine denim dyeing facilities, the wastewater generation rate was taken from a denim dyeing facility. The flowrate was divided by the area of that facility to obtain a wastewater flowrate to area ratio. The resultant factor was then multiplied with the area of the remaining eight denim dyeing units. A similar process was adopted for the other three types of industries. The method for the estimation of wastewater generation, though completely inaccurate, was the only way for evaluation as the textile processing facilities were reluctant to share their data.

2.3.2 Mapping textile industries GPS locations in KITE

The data collected during the survey of ground control points in (section 2.1.1). were converted into shapefiles and then mapped according to their sectors using the ArcGIS software.

2.3.3 Site selection for the proposed wastewater treatment plant

The slope of the study area was calculated using Shuttle Radar Topographic Mission's (SRTM) Digital Elevation Model (DEM) at 30-meter resolution (pixel size: 30x30), whereas, the land use and land cover were mapped using Landsat 8 satellite imagery (31^{st} December 2018). For this purpose, supervised classification with maximum likelihood algorithm was used. Buffer analysis from ArcGIS geoprocessing tools was used to create the buffer around primary roads. Drainage density was also mapped by the DEM. Finally, weighted overlay analysis (Table 2.4) was used to select suitable

Table 2.4: Criteria table for site suitability analysis (Wenzel *et al*., 1997)

S. No.	Criteria	Classes	Rank	Weight	Total weight
1	Slope	< 5	3	25	75
		5 –15	2		50
		> 15	1		25
2	LULC	Soil/Open area	3	35	105
		Agriculture land	2		70
		Other vegetation	2		70
		Urban	1		35
		Water bodies	1		35
3	Drainage	0 – 100	1	30	30
		100 – 200	2		60
		> 200	3		90
4	Roads	0 – 100	1	10	10
		100 – 200	2		20
		> 200	3		30

sites for the proposed combined effluent plant. The weighted overlay analysis was done as follows.

i. Each criterion was assigned a weight in the suitability analysis.

ii. Values in all criteria were converted into a common suitability scale.

iii. Criteria layers were overlaid, multiplying each criterion suitability rank value by its weight and totaling the values to derive a suitability value.

iv. The suitability values were written to new cells in an output layer. The symbology in the output layer was based on these values.

v. Weights were assigned to each criterion in the overlay process to control the influence of different standards in the suitability model.

vi. Each criterion layer's weight was multiplied by each cell's/pixel's suitability value to get a weighted suitability value.

To avoid the negative/cumulative and synergistic impacts of the textile industry effluents on the environment, it is crucial to select the site with consideration of all environmental aspects (social and ecological). The venue for the wastewater treatment plant was selected based on the following criteria (Wenzel *et al*., 1997; Subramani *et al*., 2014):

i. The slope of the surface should be less than 15%.

ii. The proposed site should be away from the densely habitated area.

iii. The site should be 200 meters away from the main roads.

iv. There should be a minimum of 200 meters distance between the site and any water body.

Wind speed and directions are also an essential factor for the selection of a suitable CETP site. In this study, a suitable site was selected for a closed treatment system, which will not be causing an odor problem. Thus, these criteria were not included in this study.

2.3.3.1 Slope

The main objective of the site selection was to reduce the energy need for pumping by selecting sites having natural slopes. KITE is in the most urbanized area of the Karachi city, with the surrounding area having a slope between slope 0 and 20 degrees. The KITE area has a gradual slope towards the Arabian Sea, which decreases along the bank of Malir River. The sector with a low slope would be more suitable for the CETP site for the wastewater collection pipes to follow the gradient towards the South West (Fig. 2.1). To calculate the slope of the study area, Shuttle Radar Topographic Mission's (SRTM) Digital Elevation Model (DEM) at 30-meter resolution (30x30 pixel size) was used (downloaded from USGS website https://earthexplorer.usgs.gov/). The slope was categorized into three categories: highly suitable (slope: 0-5), moderately suitable (6-15) and not suitable (>15).

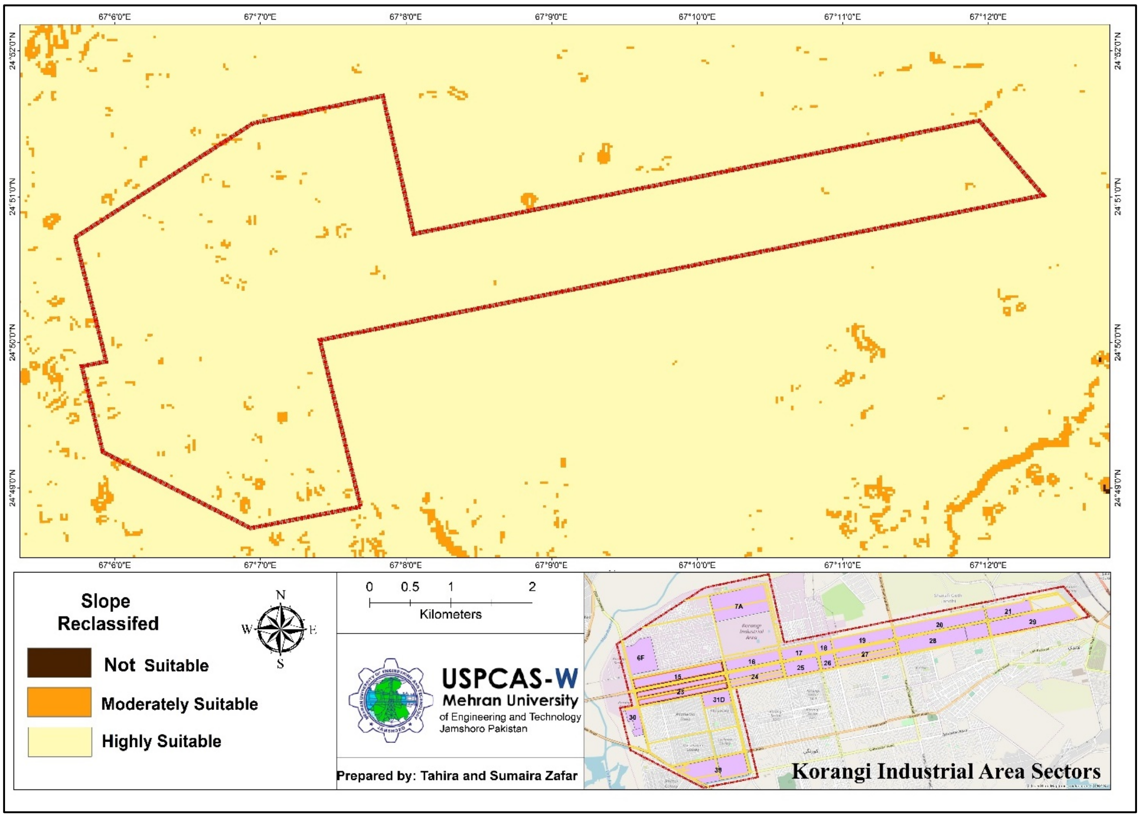

Fig. 2.1: Slope ranks (reclassification values)

2.3.3.2 Drainage density

The KITE area is located on the left bank of the Malir River Basin. Sukan and Malir Nadi are two streams that need to be considered while selecting the CETP site. Drainage density is a measure of how well or how poorly stream channels drain a watershed. Stream network was used to map the drainage density of the study area by using DEM to delineate significant streams. Drainage density was calculated by dividing the total length of all the streams and rivers in a drainage basin by the total area of the drainage basin. Areas with higher drainage densities were excluded from the study by giving the lowest weight/importance in the site selection (Fig. 2.2).

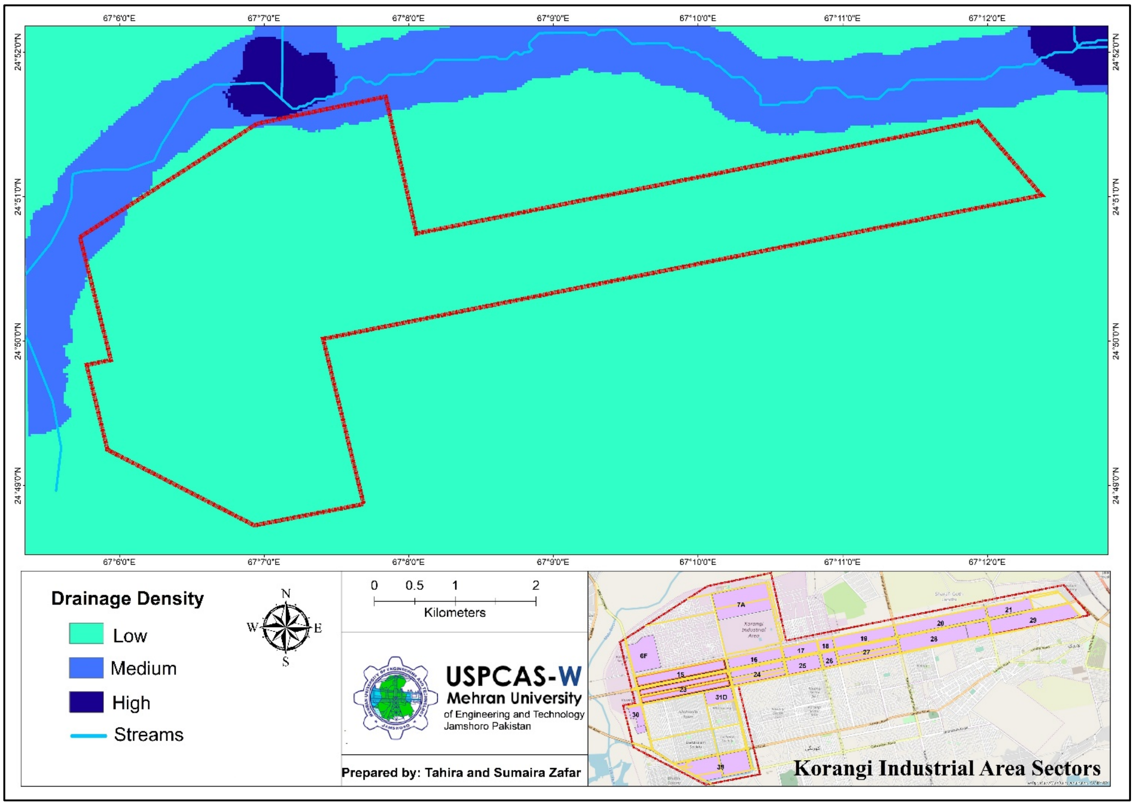

Fig. 2.2: Drainage density ranks

2.3.3.3 Land use/landcover (LULC)

As textile industries are also responsible for air emissions and production of heavily polluted wastewater, CETP must be at a significant distance from water bodies and thickly populated areas. To map the major LULCs in the study area, Landsat 8 satellite image (31st December 2018) was used to classify urban areas, agricultural areas, rivers, soil/open areas, and other vegetation using supervised classification with maximum likelihood algorithm (Fig. 2.3).

2.3.3.4 Roads

CETP should be located at least 200 meters away from roads. The road network used for the study was downloaded from open streets maps. A 200-meter buffer was applied and given the lowest rank for the CETP site. Buffer analysis from ArcGIS geoprocessing tools was used to create a buffer around primary roads (Fig. 2.4).

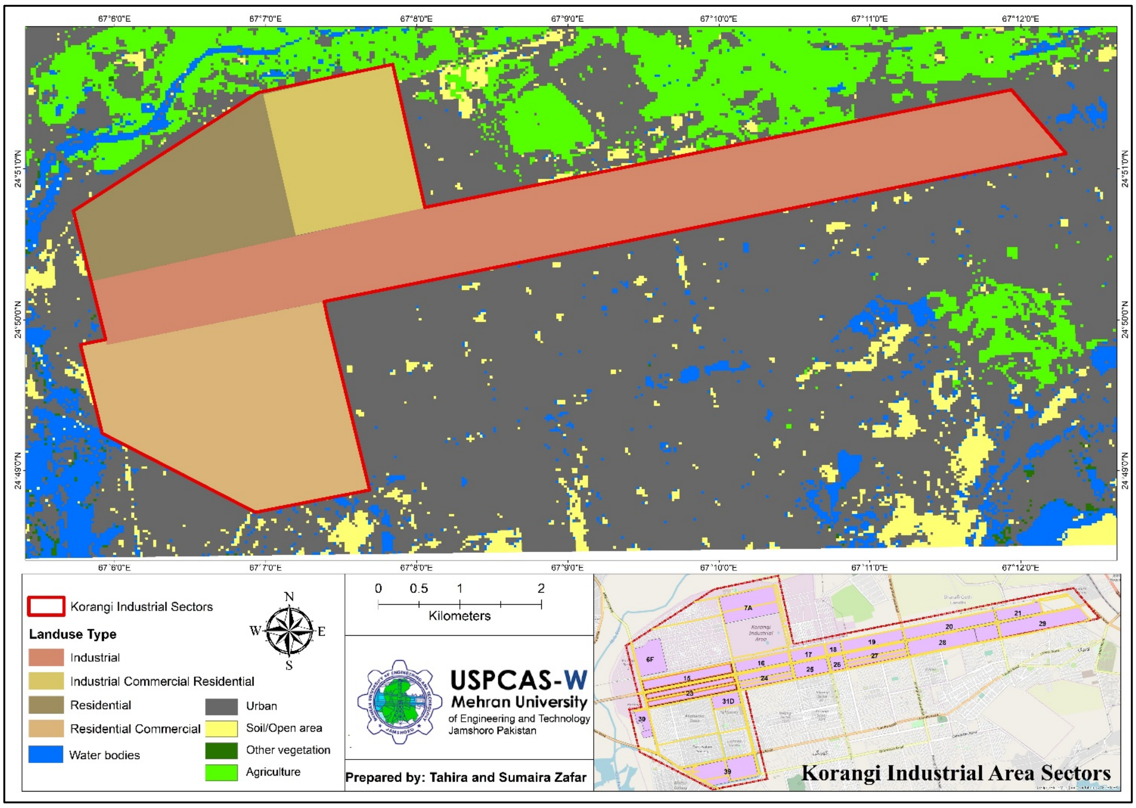

Fig. 2.3: LULC ranks

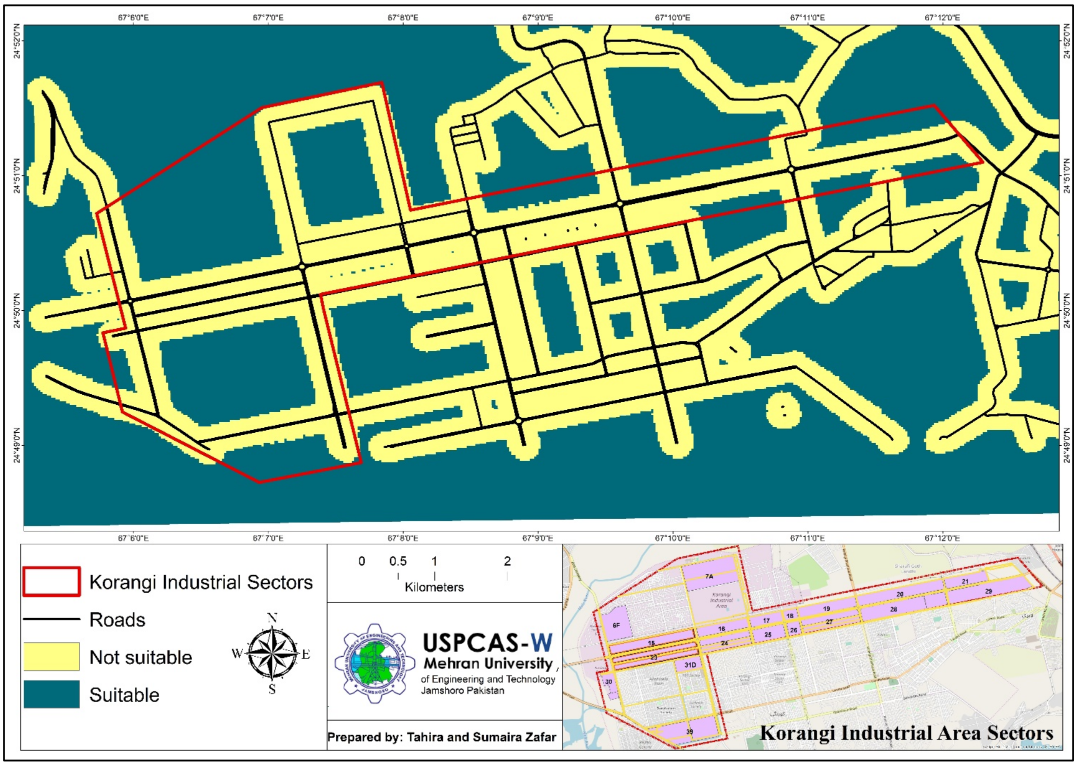

Fig. 2.4: Road network and buffer

3. RESULTS AND DISCUSSION

3.1 Surveys and Interviews

Textile processing industries are primarily divided into two categories: (i) wet-processing and (ii) dry-processing industries. In wet-textile processing, enormous quantities of water and chemicals are used in processes such as dyeing, finishing, and printing. The wet-processing industries are considered a major source of pollution in the textile sector due to the discharge of highly contaminated effluent in water bodies. On the other hand, dry processing textile industries have a relatively smaller ecological footprint because it uses fewer quantities of water and chemicals.

The first task of this project included the collection of ground control points (latitudes and longitudes) using the global positioning system (GPS) of all the textile processing units in the KITE region. The number of units located during the survey was 149, which included 51 wet-processing and 98 dry-processing units. Wet-processing industries were further classified into four categories, i.e., denim dyeing, denim washing, apparel/home manufacturing, and towel dyeing. A summary of the textile units and their processing types is shown in Table 3.1.

Table 3.1: Number and types of wet- and dry-processing industries in the KITE region

S. No.	Type of industry	Number of units
	Wet-processing textile industries	
1	Denim dyeing	9
2	Denim washing	7
3	Apparel/home	20
4	Towel manufacturing	15
	Dry-processing textile industries	
5	Spinning	7
6	Knitting	16
7	Weaving	8
8	Garments stitching printing	26
9	Silk manufacturing	2
10	Fabric and garments manufacturer	8
11	Thread manufacturing	1
12	Polyester buttons	1
13	Not specified	29

3.2 Seminars and Focus Group Discussions (FGDs)

Throughout the project, two executive seminars and four FGDs were organized. The outcomes of these activities are discussed below.

3.2.1 First seminar

The first executive seminar was organized under the theme "Industrial Wastewater Management" on August 15, 2018, at Pearl Continental, Karachi The seminar was attended by more than 60 participants, which included government stakeholders (n=15), representatives of the industries (n=20), faculty and students from academia (n=20), and media persons (n=5). The purpose of the seminar was to pave the way for networking, collaborative efforts and teamwork to improve the management of wastewater treatment in the province. The outcomes of the seminar are given below:

- ☐ The industry-academia collaboration is obligatory to be consolidated for catering to the emerging environmental problems.
- ☐ Around four thousand industrial units are being operated in Karachi without the facility of wastewater treatment plants, and 450 MGD of untreated wastewater is drained into the Arabian Sea.
- ☐ Industrial units would have to be made responsible to control untreated wastewater discharge in the Sindh Province.
- ☐ The Judicial Water Commission through the Sindh Environmental Protection Agency (SEPA) is going to complete a detailed survey on the status of compliance of its directives for installation of effluent treatment plants in SITE (Karachi), Korangi Industrial Area, Federal B Area, North Karachi Industrial Area, Industrial Hub in Ibrahim Haidri, SITE (Super Highway-4), Landhi Industrial Area, industries at Port Qasim, and other industrial areas.
- ☐ The installation of five mega effluent treatment plants has been planned for Karachi at the cost of Rs.12 billion to treat industrial wastewater. The Federal and Sindh Governments have approved these plants by committing to share the cost. The tender documents are under preparation, and the project is expected to be launched soon.

3.2.2 Second seminar

The second seminar in the series was held on the 5th of August 2019 at Avari Towers, Karachi**.** The distribution of invited participants was as follows: industrial managers (n=20), federal and provincial policymakers (n=15), civil society activists and media persons (n=10), academicians, and researchers (n=15), and international wastewater management experts (n=5). The theme of the seminar comprised of five areas listed below.

i. Current status and enhancement of industry-academia relationship for resource conservation and industrial wastewater treatment

ii. International Labor and Environmental Standards (ILES) application in

Pakistan's small-to-medium enterprises (SMEs)

iii. Collaborative participation of academia/civil society/government bodies for efficient industrial wastewater management

iv. Improvement in the environment and product quality through the Higg Index 3.0

v. Eco-unit for industrial wastewater management.

The following were the main points discoursed during the seminar.

- A productive interface between academia and industry in the present times is a critical requirement.
- One of the major hurdles between the industry-academia linkage is that the researchers' objectives are not compatible with the industrialists' demands.
- An environmental management course should be designed as per industry needs. Training for process improvements/substitutions, chemical substitution, and the Higg Index improvement should be organized.
- Emerging water pollutants have raised the need for developing advanced treatment technologies. These treatment technologies cannot be operated without adequate skills.
- Processing industries need to modify their approach in solving environmental challenges and should adopt system and sub-system changes (modify processes) to eliminate adverse impacts during manufacturing and services while consuming fewer resources and generating less waste.

3.2.3 First FGD

The first FGD was convened on December 27, 2018, at the Korangi Association of Trade and Industry (KATI) Head Office, Karachi. Invitations were sent to more than 25 industries, from which only 15 sent their representatives. The theme of the discussion was to deliberate and disseminate the concept of eco-innovation to the entire KITE region, especially the textile sector. The idea of eco-unit was successfully spread during the first FGD. The participants agreed to enhance the environmental performance of their respective units. The project team was invited by different industrial managers to visit and evaluate the environmental compliance in their units.

The salient features of the discussion are as follows.

- The concept of eco-unit was shared with the participants. They were informed about the environmental benefits by employing the system and sub-system level changes in textile processing units.
- The participants were informed about the utilization of green chemicals and dyes.

- The concept of environmentally responsible purchasing policies and substitution of raw materials with less environmentally damaging materials was also brought under discussion.
- It was highlighted that waste could be reduced by replacing chemicals in some processes with mechanical or other nonchemical treatments, such as ultraviolet radiation for disinfection.

3.2.4 Second FGD

The second FGD was held on May 3, 2019, at Zafan Hotels, Karachi. Participants were invited from 15 different organizations related to the textile industry. The theme of the discussion was “Pollution Prevention in Textile Operations”. The outcome of the discussion is stated below.

- Environmental burdens generated by the textile sector can be reduced by focusing on chemical substitution and process and equipment modification.
- Use of pad batch (cold) dyeing for rayon, blends, and cotton conserves energy, dyes, water, chemicals, labor and floor space. It does not require salt and chemical specialities, correspondingly saving money and reducing waste. In rare cases, the desired properties of the fabric may not be achieved.
- Countercurrent technique for reducing water usage must be adopted in the dyeing process. Countercurrent washing is a technique to reuse the least contaminated water from the final wash for the penultimate wash and so on until the water reaches the first wash-stage. Wash water from the first stage is discharged.
- Purchasing of raw material in returnable containers can significantly reduce the quantity of solid waste generation.

3.2.5 Third FGD

The third FGD was organized on June 27, 2019, at the FPCCI Head Office, Karachi. More than ten industrial and government stakeholders participated in the consultation, which focused on wastewater treatment and reuse options for the textile industry. The following recommendations were made:

- Industry-academia linkage is the key element to tackle emerging environmental challenges in Pakistan.
- The eco-innovation scheme is specially designed to strengthen industry-academia collaboration.
- With the increase in the production of an industry, its environmental footprints proportionally increase. Thus, a proficient environmental plan is necessary

for reducing environmental burdens.

- ☐ Many textile industries are discharging high-temperature effluent, from which an ample amount of energy can be recovered due to high temperatures by installing heat exchangers.
- ☐ Membrane bioreactor is a useful tool to treat industrial waste streams. However, membrane fouling remains a concern for its efficient operation. More investigations are needed to explore its fouling effect.
- ☐ The contamination of freshwater with metals is another upcoming issue in industries located in Karachi.

3.2.6 Fourth FGD

The fourth FGD took place on July 12, 2019, at Artistic Milliners- 2, Karachi. The Director of Operations, Quality Assurance Manager, and Technical Wet-processing Manager of the designated industry participated in the meeting. The discussion mainly focused on "Treatment and Reuse Options for Textile Effluent" while some additional points were also made during the dialog.

- ☐ The water that is being used in the dyeing process can be reused again if processed through on-site treatment.
- ☐ The respective industry was suggested three on-site treatment options, i.e., membrane bioreactor, electrocoagulation, ultra + nanofiltration assembly.
- ☐ The occurrence of sodium thiosulphate as a byproduct in the waste stream is difficult to remove. Our team was asked to study the removal of sodium thiosulphate.
- ☐ We were informed that the respective industry had started applying the eco-innovation scheme; prewash water was being utilized in post-washing, thereby lessening the stress on freshwater sources.

3.3 Environmental Auditing and Identification of Eco-innovation Options

For environmental auditing, a textile unit was selected from each type of the wet-processing industries. The objective of the auditing was the review of an environmental management plan, available options for system and subsystem changes, and suggestions for component addition options. The name of the textile units will not be exhibited in the report as per mutual agreement between the parties (the textile units and the project team). The textile units selected for environmental auditing and review of the existing environmental management plan are listed below.

i. Denim washing unit

ii. Denim dyeing unit

iii. Apparel/home textile unit

iv. Towel dyeing unit

3.3.1 Denim washing unit

The audited facility is one of the leading suppliers of premium denim fabrics and garments in the world, with a large-scale, fully vertical operation based in Karachi, Pakistan. The company has recently expanded its capacity to produce 50 million meters of fabric and 25 million garments per year. The facility has installed several technologies to ensure that they offer their customers a product of superior quality, but also implemented sustainable practices that protect their community and the environment. The process sequence of denim and garment washing is different as mentioned earlier in case of a home, apparel and denim dyeing facilities because here the raw input is the already processed and dyed denim fabric and garment, which are further processed for value-addition, i.e., denim fabric and garments appearance and patterning. The process flow of the audited facility is shown in Fig. 3.1

The investigation was carried out in the following sections.

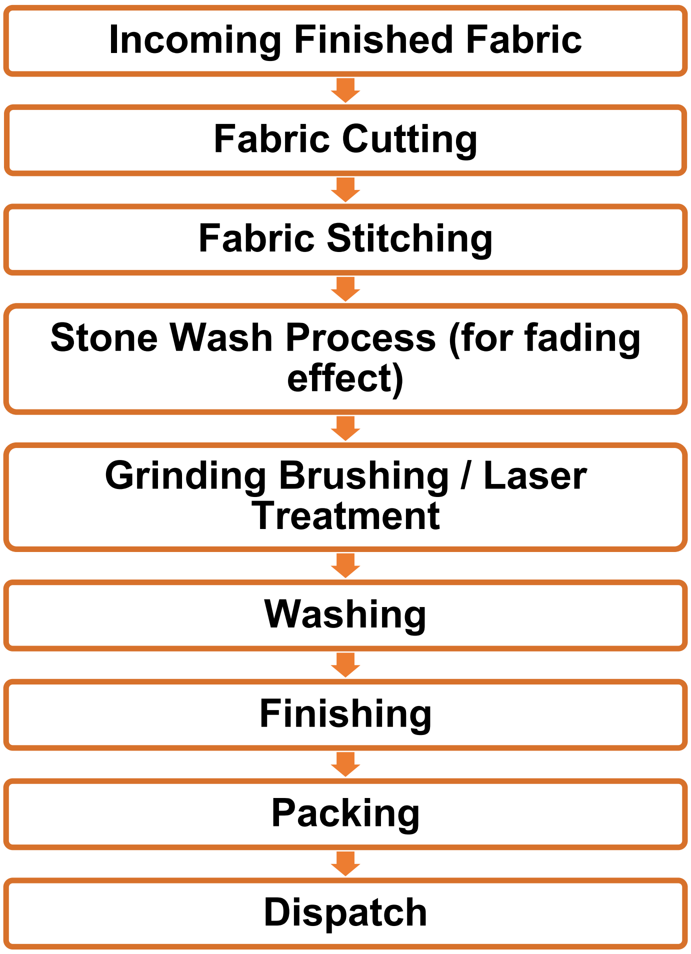

Fig. 3.1: Process flow for denim fabric/garment processing

i. Water

ii. Solid waste generation

iii. Air emission

iv. Energy

3.3.2 Water

3.3.2.1 Water consumption

Water consumed in the facility was found to be 94,680 cubic meters per month (based on the data of the last six months, i.e., Jan-June 2018), on average, which may decrease by adopting water conservation techniques. Water conservation will eventually help in reducing costs, and increasing environmental benefits as both the variables are closely linked. The four main sources of water to the facility are provided in Table 3.2.

Table 3.2: Main sources of water

S. No.	Water sources	%
1	KWSB	1
2	Hydrant (Private line)	53
3	Bore Wells (Groundwater)	38
4	Tanker (Purchased water)	9

3.3.3 Water treatment

The groundwater is treated with an RO plant installed in the industry. The ratio of RO plant's product water to reject water is 70:30, i.e., about 70% of the water fed to RO plant is recovered as product water, while the rest (30%) is wasted owing to a high concentration of dissolved salts as a result of osmotic pressure treatment. The RO water is fed to utility equipment, such as boiler and waste heat recovery boiler (WHRB). The KWSB water is not treated and used directly in the other utility sections.

3.3.3.1 Water discharge

After its use in textile processes, around 87% of the input water is discharged to the effluent treatment plant. Quantity and quality of the effluent are adequately monitored. For the quantification of the wastewater, flowmeters have been installed. For quality analysis, samples are analyzed by certified laboratories periodically. After the treatment, samples meet the SEPA, National Environment Quality Standards (NEQS), and Zero Discharge of Hazardous Chemicals (ZDHC) foundational standards. Domestic effluent has separate sewerage lines, i.e., a domestic stream is not treated in the effluent treatment plant (ETP) and is directly discharged in the main drain.

3.3.3.2 Solid waste generation

The audit team found different types of solid waste in the industry, which were noted along with its sources during the audit. The data on the generation of solid waste was acquired from the management of the designated industry. Furthermore, the disposal modes of different types of solid waste from various departments were based on the information provided, as explained in the following section.

3.3.3.3 Sources and generation rates

The management of the industry records the generation of solid waste at the departmental level. Solid waste collected by each department is transferred to a central solid waste collection yard, where it is weighed and sold for scrapping brokers, who are certified by SEPA. The data of solid waste sold out as scrap obtained from the management of the industry are reproduced in Table 3.3.

Table 3.3: Solid waste sources, types and quantities (Jan – May 2018)

S. No.	Item description	Type	Source	Unit	Total	Disposal mode
1	Medical waste	Hazardous	Dispensary	kg	1.00	Authorized vendor
2	Ink cartridge	Hazardous	Entire facility	Pcs	-	Authorized vendor
3	Printing screens	Hazardous	Printing	Pcs	-	Authorized vendor
4	Wooden scrap	Non-Hazardous	Entire facility	kg	2,545	Sold
5	Tire scrap	Hazardous	Logistic department	Pcs	-	Authorized vendor
6	Iron and computer scrap	Non-Hazardous	Entire facility	kg	16,176	Sold

3.3.4 Air emissions

Air emissions from the industry are broadly classified as point and diffused emissions. The industry is complying with the legislative part and meeting the requirements of air emissions monitoring and testing from combustion sources or point sources.

The indoor sampling and monitoring activities are to determine the degree of exposure with chemicals in use, containing formaldehyde/VOC, manganese, and respirable dust typical of daily processing activities in the following areas/departments: The monitoring results were compared with recognized Permissible Exposure Limit (PEL). No contaminants were reported to be above the permissible limits in the indoor air.

3.3.5 Review of the existing environmental management plan

The audited facility has taken the following initiatives at system and sub-system levels for environmental sustainability.

- ☐ Adopted waste heat recovery methods at power generators to produce steam
- ☐ Replacement of intensive energy boilers, compressors, and engines with new and efficient ones
- ☐ End-of-pipe treatment and RO based membrane filtration for recovery of 30% RO treated water in washing facility
- ☐ Use of metal-free, biodegradable and export quality chemicals, including surfactants, softeners, and fixers for efficient end-of-pipe treatment
- ☐ Steam condensate recovery at washing facility
- ☐ Solar power generation to meet 15% power requirement of stitching section

3.3.5.1 Suggestions for sub-system changes

After detailed analyses of resource inputs and waste streams, the below stated eco-innovation possibilities were explored and recommended to the facility for further improvement.

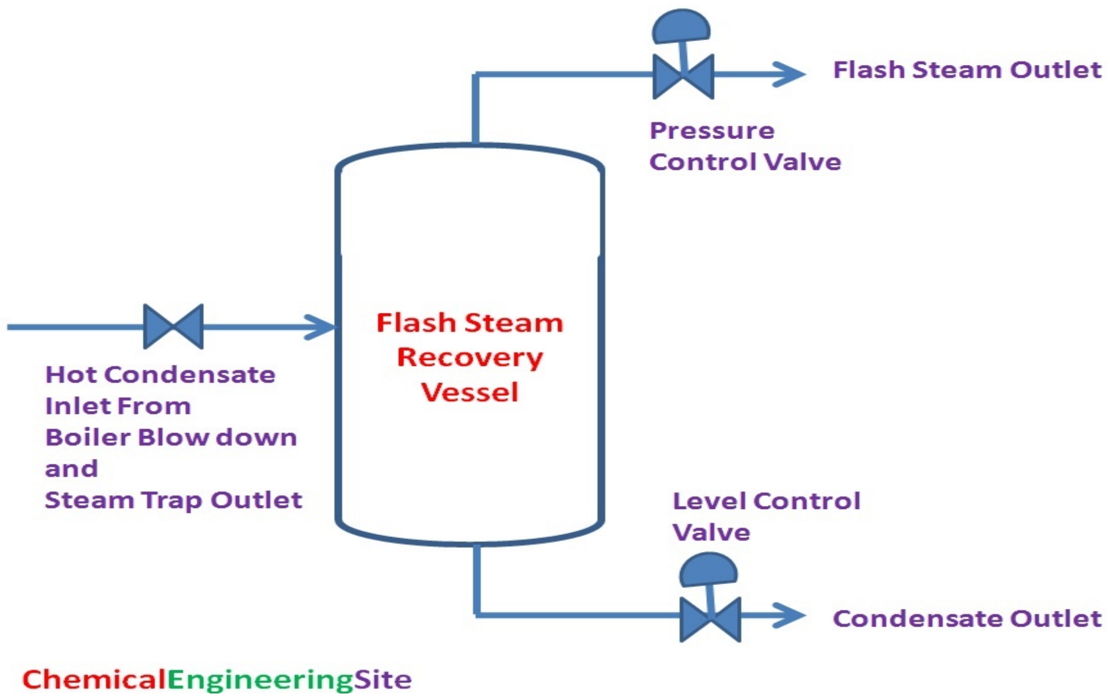

Fig. 3.2: Example of the flash steam recovery vessel

- ☐ It was noted that a high amount of flash steam was being generated from the boiler feedwater tank. This flash steam could be separated and recovered using a flash steam vessel (Fig. 3.2) and could be utilized in heating the boiler feed water with a separate line, in which flash steam could be brought in direct contact with boiler feed water. Another option is to arrange an additional boiler feed water tank in which flash steam could be brought in contact with excess boiler feed water tank for its continuous heating.
- ☐ Replacement of thermodynamics steam traps with ball-floating type steam traps
- ☐ Use of exhaust waste heat from dryers for preheating of an up-coming lot, to save energy at dryers
- ☐ Enhancement of the rate of recovery of the reclaimed water after efficient RO operation, i.e., up to 60%
- ☐ Use of RO rejected water in toilet flushing
- ☐ Setting-up recycling of drain water from hydro-extraction to the initial washing process(es), preferably for darker shades. Additionally, drain water off the ultimate washing process of lighter shades.
- ☐ Flash steam recovery at boiler
- ☐ Installation of condensers at dryers for condensation of evaporated vapors from dried fabric/garments and recovery and reuse of condensed distillate
- ☐ Thermodynamic/disc-type steam traps release and waste high amount steam, along with condensate, because of its under capacity at steam working pressure of 4-4.5 Bar_g. These steam traps could be replaced with circular/ball-type steam traps that have the functional ability in the mentioned steam pressure ranges
- ☐ Recovery of exhaust heat from dryer's exhaust (emitting hot air of around 55°C), utilizing (i) heating process freshwater and (ii) pre-drying of washed jeans pieces, before loading to steam dryers. These practices could significantly save steam consumption needed for excess heating of steam dryers or washing machine water.

3.3.5.2 Implemented projects and savings at the denim washing industry

The overall implemented subsystem and system changes option at a denim washing unit are shown in Table 3.4.

Table 3.4: Implemented projects and savings at a denim washing facility

Improved area	Improved method	Project description	Saving	Total cost (MRs)	Payback period (Yrs)
Water usage	Rain forest	Less water and energy consumption	40% water as compared to conventional washing	-	-
	Lasers	Zero water use	20%	-	-
	Ozone machines	Zero water use	Waterless washing	-	-
Energy	Waste heat recovery boilers	Using exhaust heat as fuel	20%	28	1.6
	Hot water used in absorption chillers	Using a generator's hot water as fuel	20 % from total captive gas generation	87	1.25
	LED replaced with conventional lights	Conventional light replaced with 36.5 Watt LED then it is replaced by 10.5 Watt	33%	42	4
Wastewater treatment	Recycling	Recycled treated wastewater	30%	35	1

**Data Source: Denim washing industry in KITE*

3.3.6 Denim dyeing unit

In the denim processing yarn, plies/ropes are dyed mostly with indigo (blue) and sulfur (black) dyes at continuous indigo dyeing machines. Afterward, the dyed yarns are weaved and further processed (mercerizing, finishing and washing), as shown in the scheme given in Fig. 3.3.

The wastewater streams of indigo dyeing processing are known as most waste loaded streams because of a high accumulation of salts, caustic soda, indigo- and sulfur-based

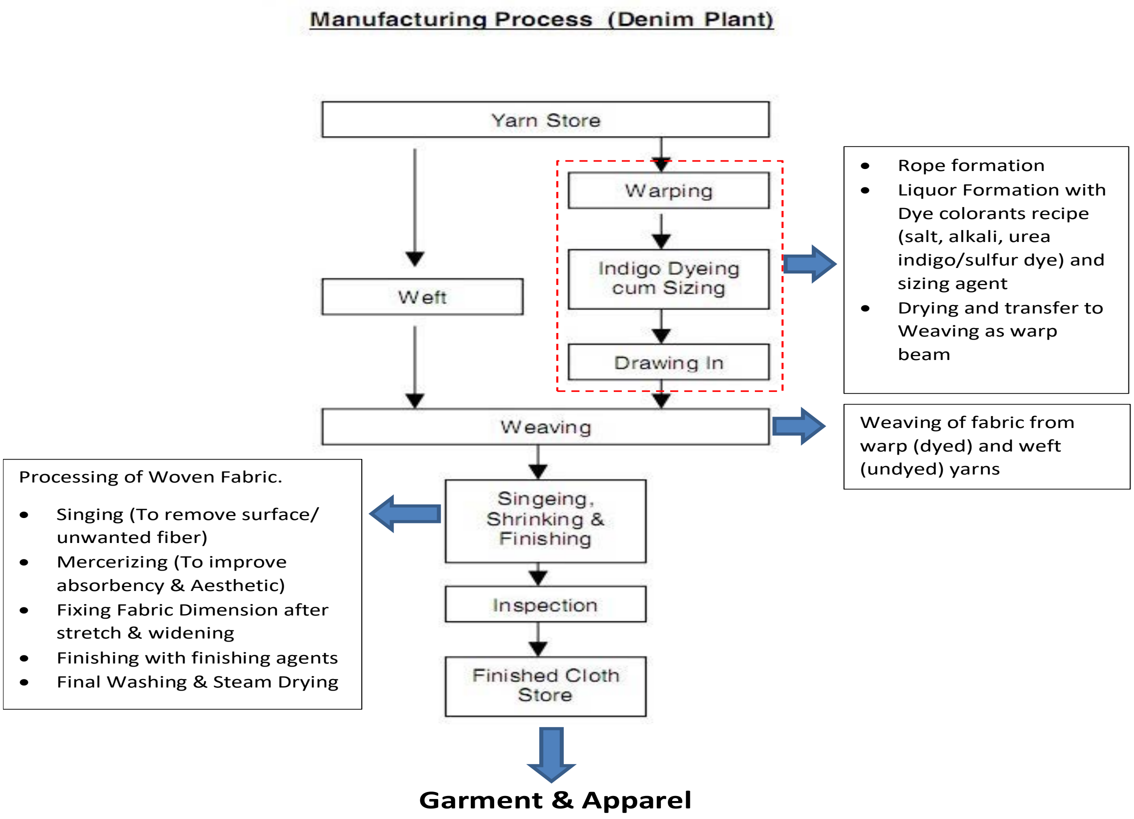

Fig. 3.3: Schematic of a denim processing sequence for indigo/sulfur dyeing and final finishing

dyes and suspended solids (in the form of detached fibers from yarns). Therefore, during the environmental examination, a strong emphasis was given to explore indigo dyeing and identification of component changes or modifications for load minimization at source and with the indigo dyeing process.

During the indigo process, the raw material (plied ropes) underwent different stages like pre-caustification, air oxidation, indigo or sulfur dyeing, washing, and drying. As per field observations and discussion with those concerned, the process understanding was as follows: (i) pre-caustification of ropes with caustic soda for improved absorbency, (ii) indigo or sulfur or a combination of indigo and sulfur dyeing, (iii) air oxidation, (iv) washing of dyed ropes and removal of unfixed dyes, and (v) drying of dyed and washed ropes and wrapping on beams. The overall sequence is given in Fig. 3.4. The chemicals used for indigo dyeing are an indigo dye, hydrogen sulfite, caustic soda, and

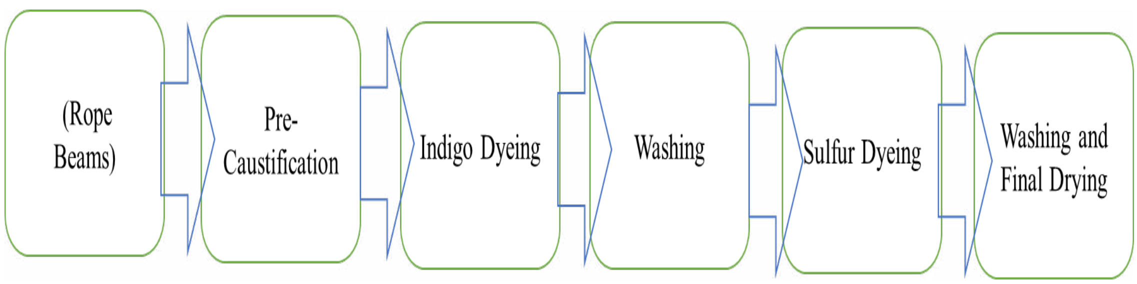

Fig. 3.4: Flow diagram of the indigo dyeing process

sodium bisulfate, while for sulfur dyeing sodium bisulfite, caustic soda, wetting agent and sulfur dye are used. The left-over liquor of indigo bath is stored in the storage tank and disposed of when necessary, while for sulfur dye bath, there are no storage options due to instability and rapid change of liquor composition. After each dyeing step, the dyed ropes are washed and rinsed for removal of a fraction of hydrolyzed/unfixed dye and final drying of ropes on steam-heated cylinders. In the overall process, separate wastewater drains were observed after pre-caustification, indigo-washing, a sulfur bath, and sulfur wash. All these streams were combined before ultimate disposal, and a schematic representation is given in Fig. 3.4.

3.3.6.1 Review of the existing environmental management plan

The audited facility has taken the following initiatives for waste minimization during indigo/sulfur dyeing, controlling waste emissions, and conservation of resources (water, energy).

- ☐ Recovery of indigo dyeing leftover in a large storage tank and reuse for the same lot or dyes shades
- ☐ Adequate process sequencing/scheduling, by which one lot is continuously dyed and washed either with indigo dye or sulfur or combined indigo/sulfur. This allows water and energy conservation by avoiding rapid process changes and fresh preparation.
- ☐ Adopted waste heat recovery at boilers, power turbines, and generators for the production of steam and heating process water
- ☐ Cooling water and condensate recovery from indigo dyeing and mercerization processes
- ☐ Effective end of pipe treatment of wastewater and disposal as per SEPA guidelines and customers' requirements of zero discharge of hazardous chemicals (ZDHC).

3.3.6.2 Identification of a system change (closed-loop system) at a denim dyeing facility

A closed-loop system is designed to circulate a product within the society as long as possible to maximize the usability of the product while reducing environmental impacts. The closed-loop system comprises of efficient use of water, energy, and resources throughout the lifecycle of the product. In this system, fabric after usage is not discarded into the environment but is purchased by the industry to recycle it as a raw material in place of cotton. The typical steps of a closed-loop system in the textile industry are shown in Fig. 3.5.

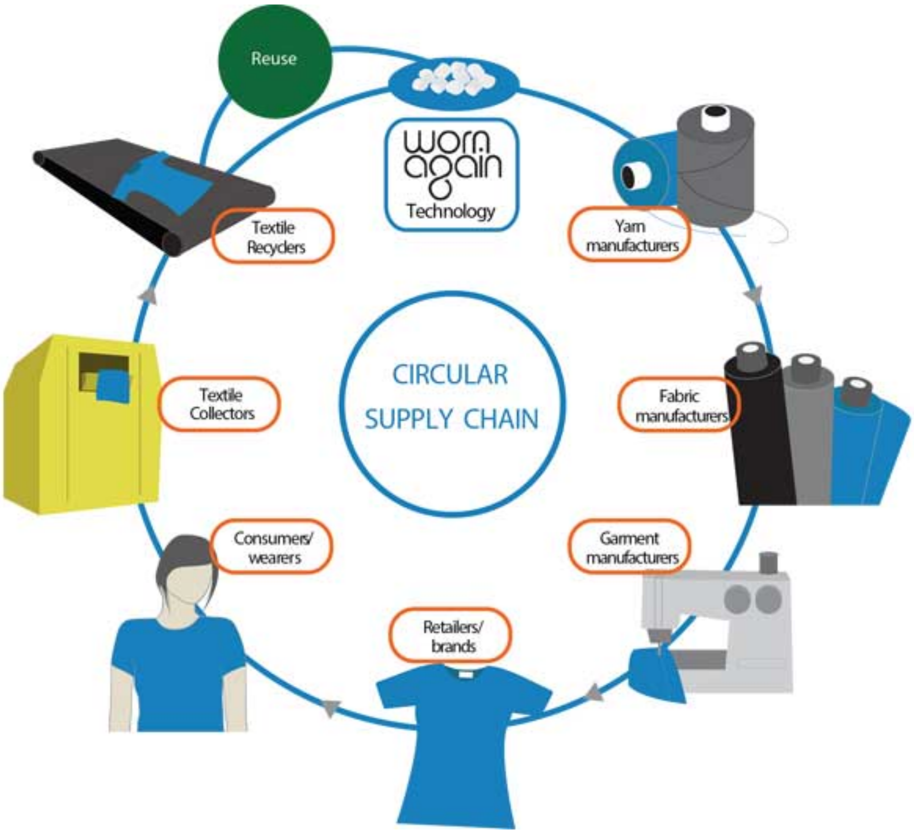

Fig. 3.5: Closed-loop system employed in the textile industry where raw cotton is replaced with recycled fabric (https://www.ecotextile.com/2015033021379/fashion-retail-news/retailers-plan-closed-loop-chemical-recycling.html)

The audited denim dyeing facility was implementing a closed-loop system in its operations to conserve water, minimize pollution load and utilize resources efficiently. The organization used to purchase discarded denim from its designated suppliers throughout the world. The denim was then shredded and made into yarn for use as a raw material in replacement of the raw cotton. This denim recycling activity is costing the industry $0.10 more per piece of denim production. However, it accounts for value addition and increased competitiveness.

Estimation of potential freshwater conservation through a closed-loop system in the denim sector in Pakistan

The annual denim production in Pakistan is about 600 million meters. There are forty major denim production tycoons in Pakistan, who contribute significantly to the denim exports of Pakistan (Memon, 2011). The amount of water required to produce 1 kg of cotton is around 20,000 liters (https://www.worldwildlife.org). Based on 600 million meters (360-420 million kg) annual denim production in Pakistan, it required 1,583,779 to 1,847,742 imperial gallons of water per annum in the production of cotton as a raw material, which can be saved in a closed-loop system. Pakistan, already a water-scarce country, requires the implementation of a closed-loop system in textile processing units to not only conserve water but also to help uplift the economy.

3.3.6.3 *Components addition suggestions to the denim industry*

The wastewater analyses of the collected samples were done at USPCAS-W, MUET. The analytical data showed that indigo dyeing wastewater carried the high ionic inorganic load (due to various chemicals in use) and organic load (mainly cellulosic fibers lost during processes). For the effective treatment of mixed effluent of the overall industry, it is crucial to deal with the wastewater of the indigo dyeing process on-site to avoid high loading from the indigo dyeing process in the mixed effluent. Based on the preliminary investigation, two possible on-site wastewater treatment and load minimization options were proposed to the facility as component addition options:

1. Anaerobic-aerobic membrane bioreactor
2. Integrated sand filtration microfiltration and ultrafiltration/nanofiltration system
3. Anaerobic-aerobic membrane bioreactor

A membrane bioreactor is an advanced biological treatment process. It combines membrane technology with biological processes that improve the degradation process. A conventional membrane bioreactor contains an aerobic/anaerobic digester and a membrane that is immersed in the digester or installed externally. The primary purpose of the membrane is to filter out the effluent while retaining the sludge in the reactor for a maximum period. Some advantages of the membrane bioreactor include smaller footprint, i.e., it requires a significantly lower area for installation compared to a conventional biological treatment unit, and provides excellent effluent quality and less sludge production. The membrane bioreactor has been successfully applied to textile industry wastewater with 97% of COD removal, up to 70% ammonia elimination, and a 70% decrease in the color of the water.

Anaerobic-aerobic membrane bioreactor (Fig. 3.6) is a new configuration of membrane bioreactor in which wastewater is first introduced in the anaerobic reactor followed by the aerobic reactor and then finally filtered out from the membrane. There are two main reasons for providing this configuration to indigo and sulfur wastewater. Combining aerobic and anaerobic treatment processes enhances the degradation process. Besides, nitrification and denitrification cannot be carried out in a single process. As the audited facility (denim) wastewater contains a high amount of nitrogen, nitrification and denitrification are necessary for the removal of nitrogen compounds from the wastewater. For the three considered feed outputs, the experiments have shown that the average removal of the COD is 97%, that of ammonia nitrogen is 70%, and that of color is 70%. However, there are some limitations to operating an MBR. It cannot remove the pigment present in the wastewater from the textile industry. Additionally, membrane fouling remains a concern.

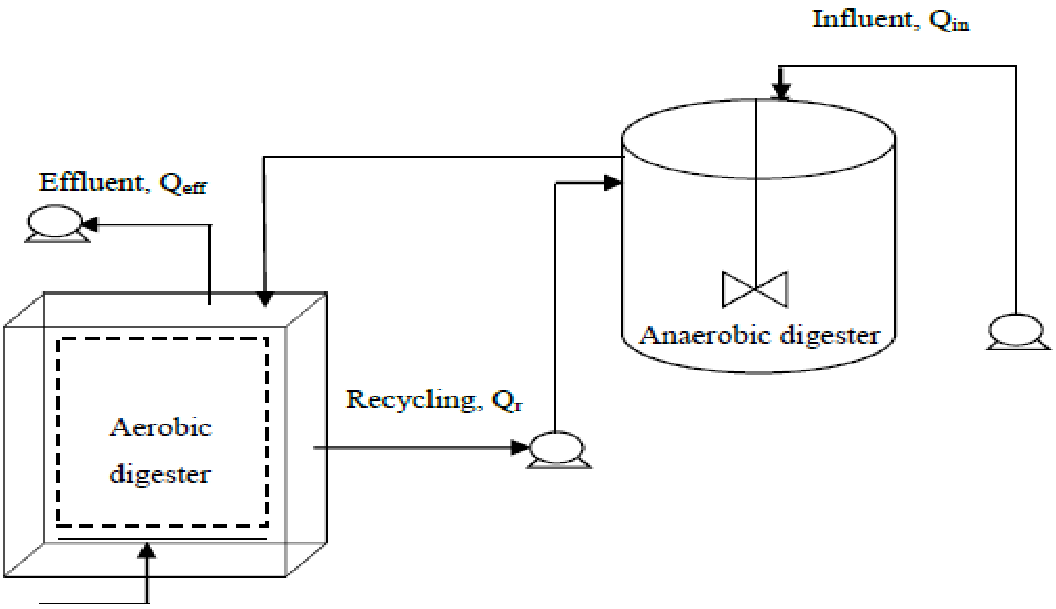

Fig. 3.6: Schematic diagram of anaerobic-aerobic membrane bioreactor

i. Integrated sand filtration, microfiltration, and ultra/nanofiltration system

It is an integrated system that combines sand filtration, microfiltration, and ultrafiltration operations (Fig. 3.7). Sand filtration is a process in which the treatment of the water is realized by the 'porous' nature of a sand layer, which traps particles present in water. A sand filter can trap particle size greater than 0.15 mm. After removing colloidal particles through a sand filter, the sand filtered water is passed through the microfiltration membrane for the reduction of macromolecules and suspended particles. Thus, pretreatment with microfiltration of wastewater is necessary because the pH of indigo dyes is 11-12.5, and if ultra/nanofiltration is used without pretreatment, then membrane

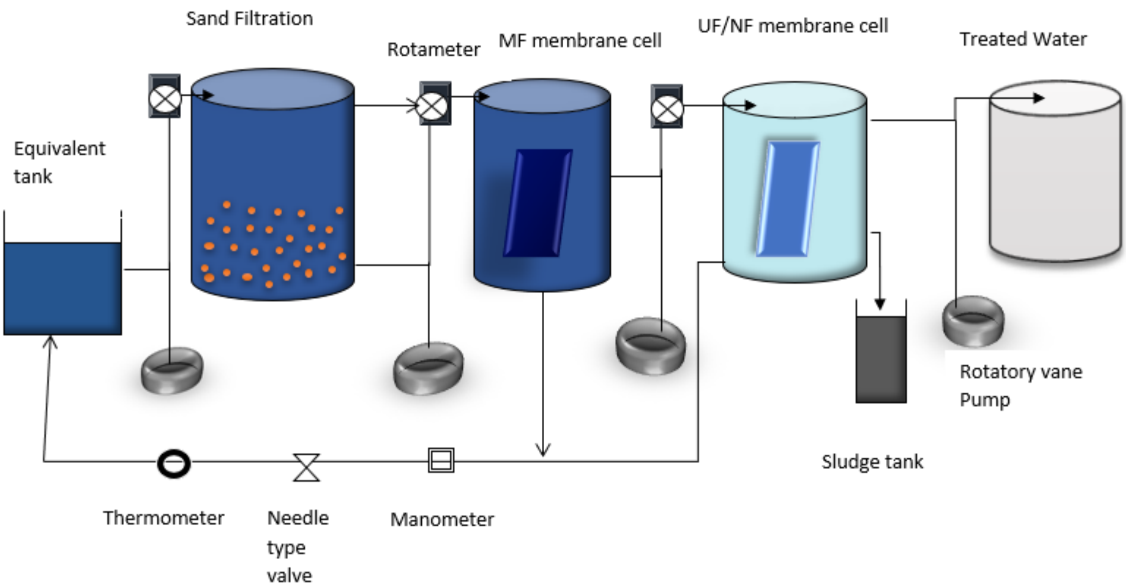

Fig. 3.7: Schematic diagram of integrated sand filtration, microfiltration and ultrafiltration/nanofiltration system

fouling occurs. Due to this reason, the integration of both membranes is necessary. Around 50% treated water to be obtained by using ultrafiltration as pretreatment. Color removal 99%. Around 86-96% and 98% rejection of salts can be achieved.

3.3.6.4 Implemented projects and savings at the denim dyeing industry

The overall implemented subsystem and system changes option at a denim dyeing unit are displayed in Table 3.5.

Table 3.5: Implemented projects and savings at a denim dyeing facility

Improved area	Improved method	Project description	Savings	Total cost (PKR)	Payback (years)
Water use	Installation	Installation of flow meter and level sensors	10.42% water	150000 - 250000	1-3
	Technique	The stoichiometric calculation for an exact amount of water			
Wastewater treatment/ reduction	Installation	Installation of conventional treatment plant	96% COD, 99% BOD and 99% TSS removal	-	-
	Management	Reuse of pre-ash water to post-wash	7% of water	No cost involved	-

**Data source: Denim dyeing industry in KITE*

3.3.7 Apparel/home textiles unit

The audited home textile processing industry is the producer of around 100 million meters of home textiles per annum, out of which 50-60% are exported. This industry follows the processing sequence shown in Fig. 3.8, starting from pretreatment, i.e., de-sizing, bleaching, mercerizing, dyeing/printing and finishing of woven fabric at continuous machines.

3.3.7.1 Review of the existing environmental management plan

This facility has followed eco-innovation components with sub-system and system changes for waste minimization and resource conservation and adopted the following measures.

- Optimization of water-use efficiency in wetting machines with average water consumption of 67 liters/kg processed fabric.
- On-site water recycling and reuse at post-washing of bleaching and mercerizing (the scheme is given in Fig. 3.9). An estimated 20% of water consumption is reduced.

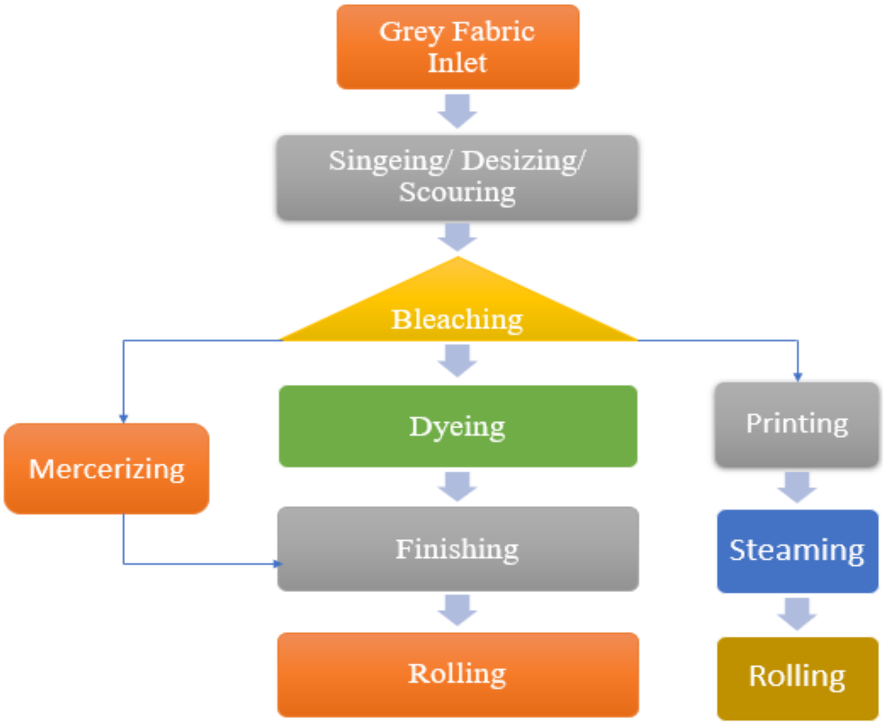

Fig. 3.8: Typical sequence of home/apparel textile processing (Ali *et al.*, 2016)

The audited facility has adopted a waste heat recovery system. Most of the textile processes are energy-intensive and use hot water for processing. Therefore, the wastewater generated has a temperature in the range of 60 to 80°C, which could reduce the dissolved oxygen concentration in water and hinder biological growth in downstream treatments. The use of waste heat recovery and heat exchangers

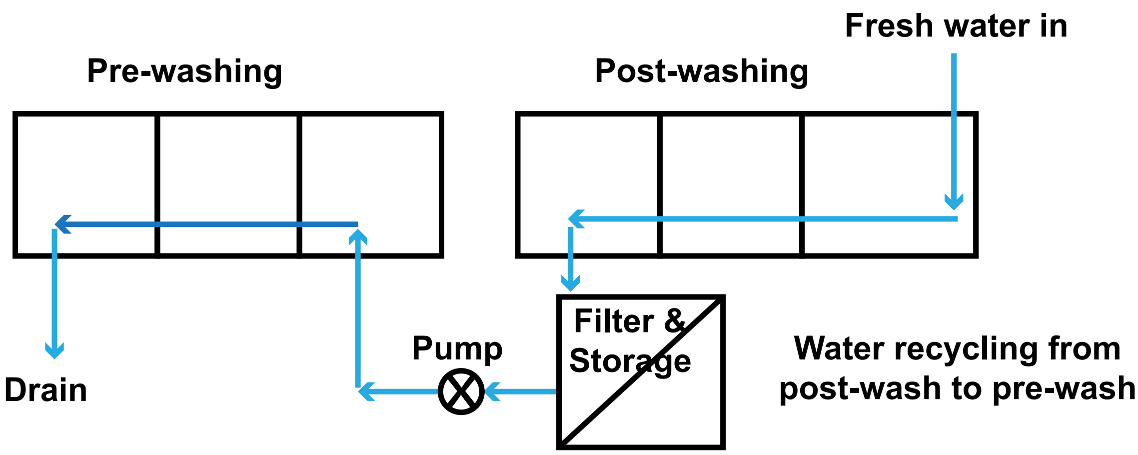

Fig. 3.9: Water recycling and onsite reuse (Ali *et al.*, 2016)

(shown in Fig. 3.10) can reduce the temperature of wastewater by exchanging its heat indirectly to freshwater entering the machines/process. This practice also minimizes steam consumption and energy input of processes.

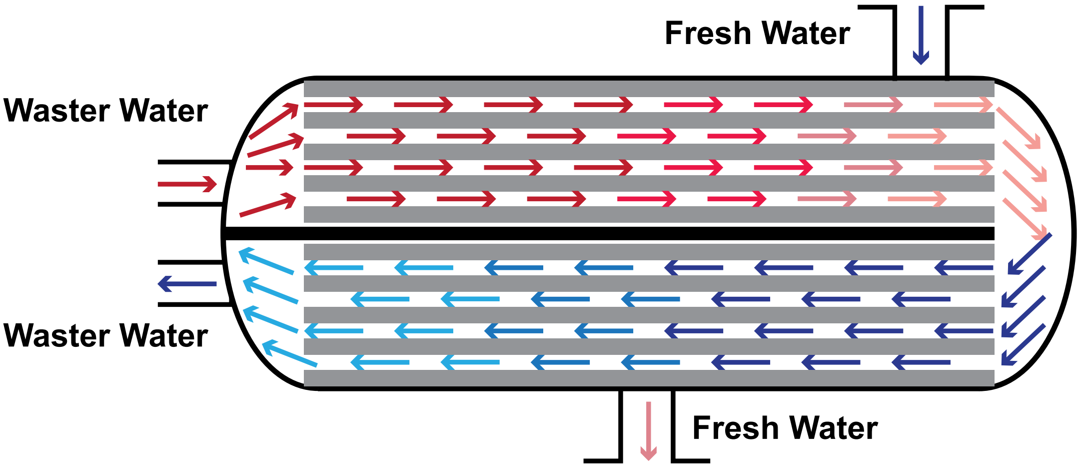

Fig. 3.10: Shell and tube heat exchange (Ali *et al*., 2016)

- ☐ Cooling water is an industrial term referred to the use of freshwater for cooling purposes. Commonly in most of the industries, the cooling water used in singeing and dyeing processes is wasted due to the failure of pumps. However, the audited facility is managing cooling water recovery by running it in open loop for textile processes, in which freshwater is pumped for cooling and afterwards received back in the pumping storage tank.
- ☐ Steam condensate is produced after the condensation of saturated steam (used for heating process water), i.e. when the latent heat of the steam is utilized and condensed into liquid (near to boiling temperature). If the steam condensate is not recovered properly, it is drained out along with produced wastewater that increases its temperature. However, the effective recovery minimizes the mixed wastewater temperature before end-of-pipe treatment and conserves water and energy. The typical scheme of the condensate recovery system is given in Fig. 3.11. The audited facility was recovering 60% of the steam condensate.
- ☐ The facility had adopted waste heat recovery systems at steam boilers, power generators, and power turbines by which exhaust emissions are utilized to heat process water or produce steam, as given in Fig. 3.12. With this system, 30% of fuel energy was being conserved at the audited facility.

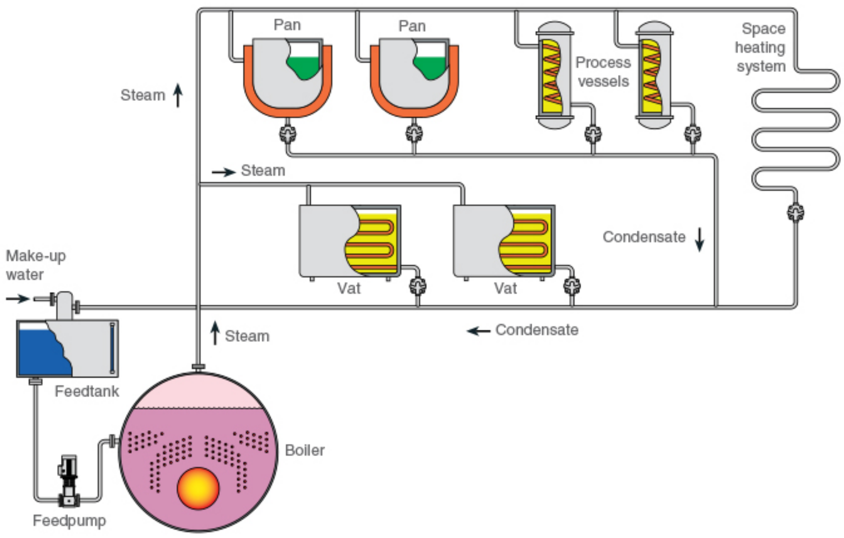

Fig. 3.11: Scheme for steam production, usage and condensate recovery cycle (Ali *et al.*, 2016)

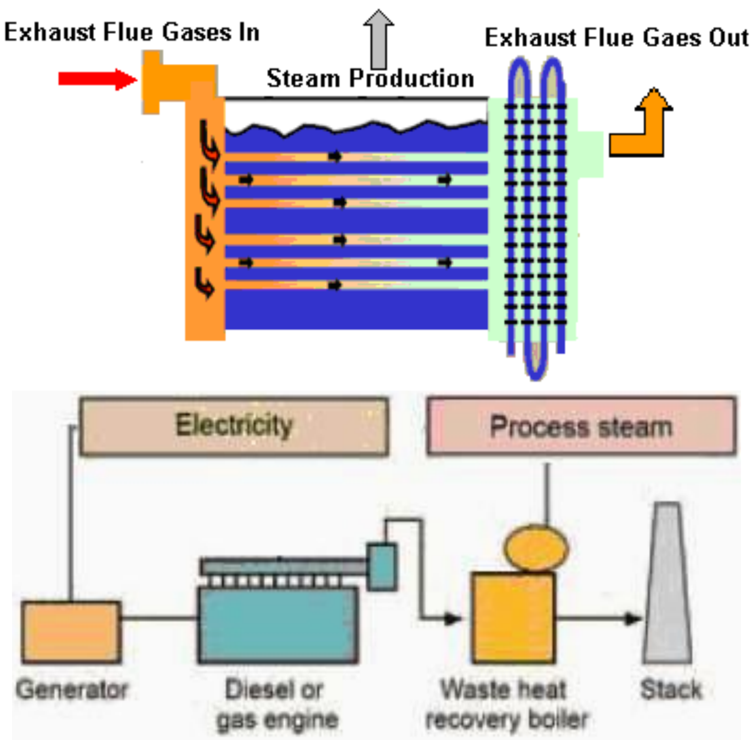

Fig. 3.12: Schematic of exhaust waste heat recovery for steam production (Ali *et al.*, 2016)

- Caustic soda recovery after the mercerization process can minimize a load of dissolved solids and pH in the mixed wastewater. The scheme of caustic recovery plant is given in Fig. 3.13. The audited facility was utilizing 90% of caustic soda during mercerization. Moreover, separated distillate water was being recovered and reused.

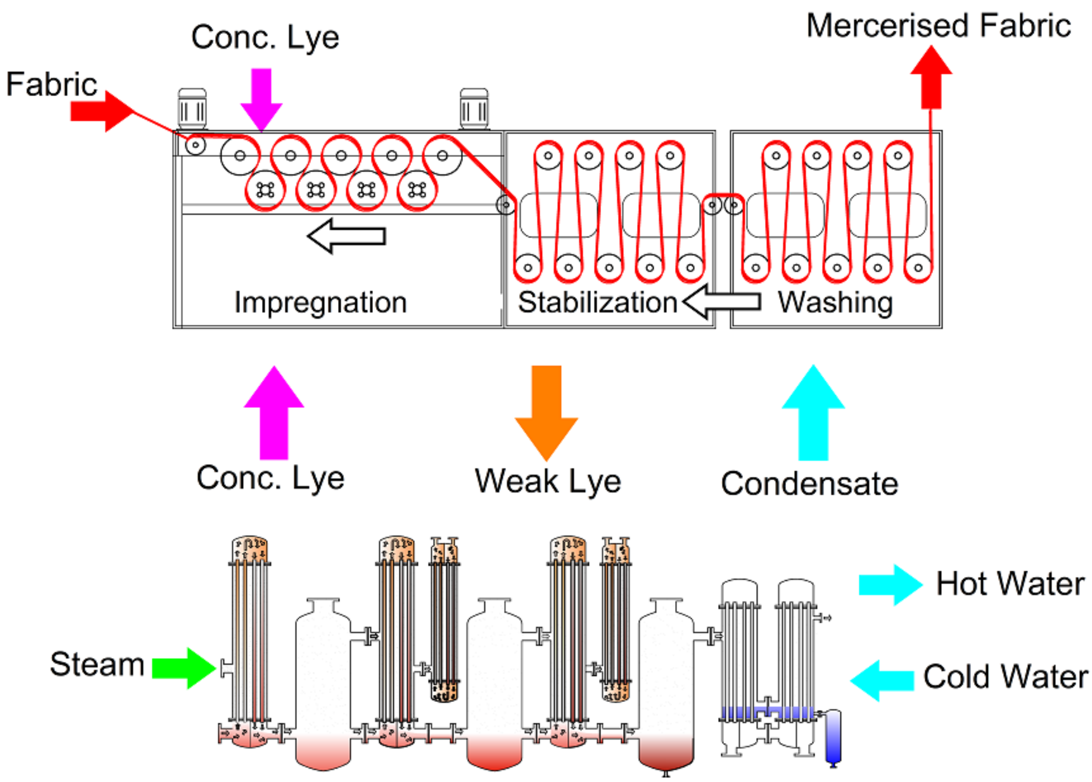

Fig. 3.13: Schematic of mercerize process and caustic soda recovery (Ali *et al.*, 2016)

- Efficient end-of-pipe treatment and 65% recovery and reuse of generated wastewater through membrane biological reactor and reverse-osmosis membrane-based filtration (Fig. 3.14) was being done at the audited facility.

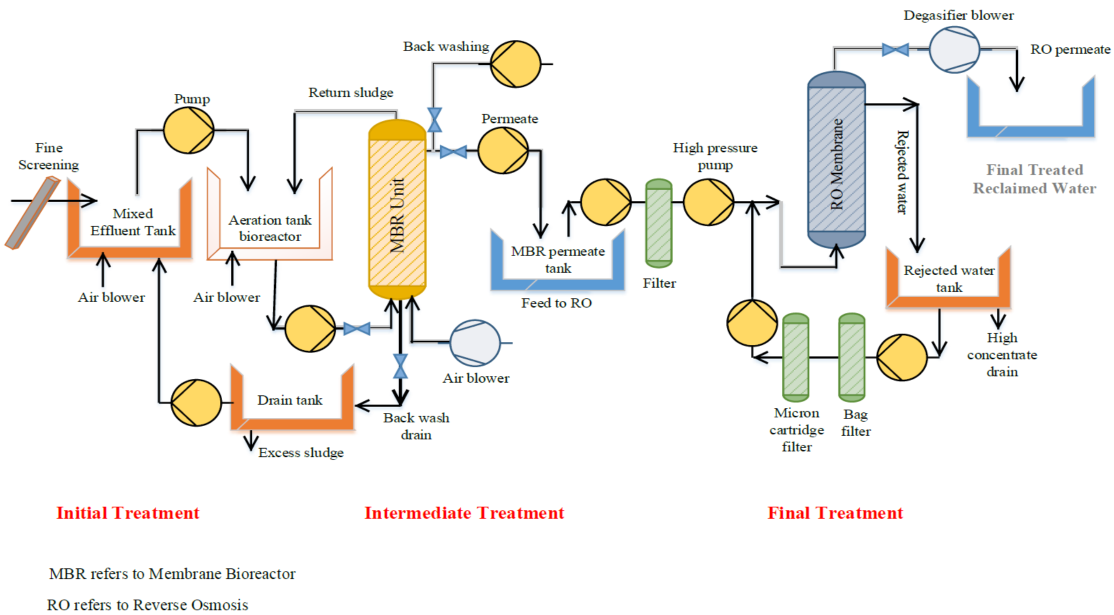

Fig. 3.14: Schematic of end of pipe treatment of wastewater and reuse (Ali *et al.*, 2016)

3.3.7.2 Implemented projects and savings at the apparel/home textiles industry

The overall implemented subsystem and system changes option at an apparel/home unit are displayed in Table 3.6.

Table 3.6: Implemented projects and savings at an apparel/home textiles facility

Improved area	Improved method	Project description	Savings	Total Cost	Pay Back (years)
Air	Management	Neutralization of wastewater by powerplant emissions	CO_2 emission reduction of 190,000 kg year	$30,000	3.8
Wastewater Treatment / Reduction	Installation	Installation of MBR	96% COD, 96% TDS removal	$2,500,000	No pay back
	Installation	Condensate recovery system	60% recovery of steam condensate	-	-
Water Reuse	Installation	RO plant	75% water reuse	$1,400,000	No pay back
	Technique	Reuse of water at post washing from bleaching and mercerizing	20% of water reuse	No major cost involved	-
Energy	Installation	Waste heat recovery system	30% energy saving	PKR150,000-250,000	1.5

**Data source: Home textile industry in KITE*

Since the audited facility had already adopted the technological eco-innovation including component addition and system and sub-system levels changes, along with the implementation and adoption of best practices in the textile processes, the audited facility was recommended to follow further non-technological component changes/ additions that could give business and marketing advantages to the industry.

3.3.8 Towel dyeing unit

The audited unit is a leading towel manufacturer, and exporter from Pakistan with a modern, state-of-the-art plant and machinery to produce high quality finished towels, bedding, and kitchen linens. The mill has a vertically integrated setup that allows all production within the premises. The facility has one of the largest air-jet terry weaving, yarn-dyed, and jacquard towel capacities, equipped with modern continuous-range and exhaust machinery. With an annual capacity of 40 million pounds of finished terry towels, the organization relies on the latest technology to ensure quality and on-time delivery. With independent power generation and negligible shortages in gas supply, the facility enjoys full capacity utilization. Due to vertical integration, all the processes are under one management. The vertical integration not only gives good control over all steps of production but also, most importantly, it contributes towards efficiency and lower cost of production. Their recent developments for environmental sustainability include recycling of wastes (hot water and hot air) and installation of the largest textile effluent treatment plant in Asia to recycle more than 80% of the wastewater from textile processes. Besides, they have collaborated with USPCASW, for the development of wastewater treatment plant to improve the process and recycled water efficiency. The processing section of ATI is equipped with continuous and exhaust range machinery. The textile processing sequence is: (i) Continuous singeing-desizing, (ii) Continuous/exhaust scour-bleach, (iii) Continuous mercerization, (iv) Continuous/exhaust dyeing, (v) Continuous printing and (vi) Continuous finishing.

3.3.8.1 Review of the existing environmental management plan

- ☐ Water usage: 1,050,000 gallons per day
- ☐ Waste heat recovery for steam production, 30% of the total steam capacity
- ☐ Wastewater heat recovery for heating process water and reduction of 8-10% energy requirement on process heating
- ☐ Reduction of 18% (200,000 gallons/day) water consumption through the process and chemical modification, on-site wastewater recovery and reuse, steam condensate, and cooling water recovery. Reduction of rinsing and washing cycles, lowering of liquor ratio in exhaust bleaching and dyeing
- ☐ Intensive wastewater treatment and 60-65% water reuse after membrane treatment

3.3.8.2 System and subsystem recommendations

- ☐ Installation and use of caustic recovery plant for recovery of NaOH from mercerization drain water
- ☐ Replacement of micron filters with ultrafiltration membranes for effective pre-treatment of RO feed and improved membranes life
- ☐ Replacement of PAC coagulant with alum for effective and improved coagulation and flocculation
- ☐ Use of sieve filtration during cone dyeing for on-site reduction of suspended solids load

3.3.8.3 Implemented projects and savings at the towel dyeing industry

The overall implemented subsystem and system changes option at an apparel/home textiles unit are shown in Table 3.7.

Table 3.7: Implemented projects and savings at a towel dyeing facility

Improved area	Improved method	Project description	Savings	Total cost	Payback (years)
Energy	Installation	A waste heat recovery system	30% steam 8-10% energy	150000-250000	1.5
Wastewater Treatment/ Reduction	Installation	Installation of treatment plant	88% COD removal	-	-
	Installation	Condensate recovery system	Recovery of steam condensate	-	-
Water Reuse	Installation	RO plant	80% of water reuse	1400000 $	-
	Technique	Process modification	18% of water reuse	No major cost involved	-

**Data source: A towel dyeing industry*

3.4 Evaluation of Environmental Damage Prevention through Lifecycle Impact Assessment

Life Cycle Assessment (LCA) is a method used to evaluate potential environmental impacts generated during the life cycle stages of a product from the extraction of raw material to the disposal or reuse. Phases of LCA include quantification, assessment, and interpretation of environmental impacts caused by the processing of a product. Environmental impacts were estimated using a user-friendly life-cycle assessment software SimaPro (Version 8.0).

3.4.1 Selection of different implementation scenarios and ecological damage assessment using SimaPro

Two different implementation scenarios were generated, and their impacts were compared with the current situation for ecological damage assessment.

Current Scenario

Under the current scenario, most of the textile dyeing industries in Karachi are operating without the facility of a wastewater treatment plant; therefore, it was assumed that the wastewater was being discharged without treatment. There was no reuse or reclamation of water is in practice within the industry. Furthermore, the measures related to ecological damage prevention have not been taken.

50% Implementation Scenario

This scenario reflects that half of the wastewater is being treated using the conventional treatment method or membrane bioreactor, depending on the industry. Moreover, the results were analyzed after considering the implementation of suggestions and recommendations given to the industries.

100% Implementation Scenario

The data related to this scenario was taken from the industries after the successful implementation of subsystem changes and component addition options.

3.4.2 Assessment of ecological damage prevention in different scenarios

Evaluation of ecological damage prevention was done by using SimaPro software that compared both implementation scenarios with the current scenario. The following impacts related to ecological damage assessment were compared. The results of each impact category are depicted in Table 3.8 and presented in Fig. 3.15.

Climate change: Global Warming Potential (GWP) over 100 years.

Freshwater eutrophication: Expression of the degree to which the emitted nutrients reach the freshwater end compartment (phosphorus considered as a limiting factor in freshwater).

Marine eutrophication: Expression of the degree to which the emitted nutrients reach the marine end compartment (nitrogen considered as a limiting factor in marine water).

Water resource depletion: Freshwater scarcity - the scarcity-adjusted amount of water used

For the current scenario, the value of climate change potential was very high due to the wastewater not being treated properly. The discharge effluent contributed to CH_4 emissions, whereas the emissions from boilers contributed to CO_2. This impact reduced in 50% implementation scenario due to the treatment of 50% of the generated wastewater. Furthermore, a quantity of the emissions from boilers was used in maintaining the pH of the wastewater.

Table 3.8: LCA results presented per unit of the functional unit

Impact category	Unit	Current scenario	50% Implementation scenario	100% Implementation scenario
Denim dyeing				
Climate change	kg CO_2 eq	50	25.2	10.1
Freshwater eutrophication	kg P eq	0.53	0.403	0.269
Marine eutrophication	kg N eq	3.47	1.73	1.04
Water resource depletion	m^3 water eq	50	39	39
Denim washing				
Climate change	kg CO_2 eq	114.64	57.00	0.00
Freshwater eutrophication	kg P eq	32.69	24.35	16.35
Marine eutrophication	kg N eq	65.61	49.21	32.80
Water resource depletion	m^3 water eq	66.00	46.20	26.40
Apparel/home textiles				
Climate change	kg CO_2 eq	27214.41	14556.21	1898
Freshwater eutrophication	kg P eq	250.00	186.14	122.28
Marine eutrophication	kg N eq	160.00	80.73	1.46
Water resource depletion	m^3 water eq	1518251.50	777574.35	36897.20
Towel manufacturing				
Climate change	kg CO_2 eq	20.03	10.93	1.84
Water resource depletion	m^3 water eq	625.20	437.64	250.08

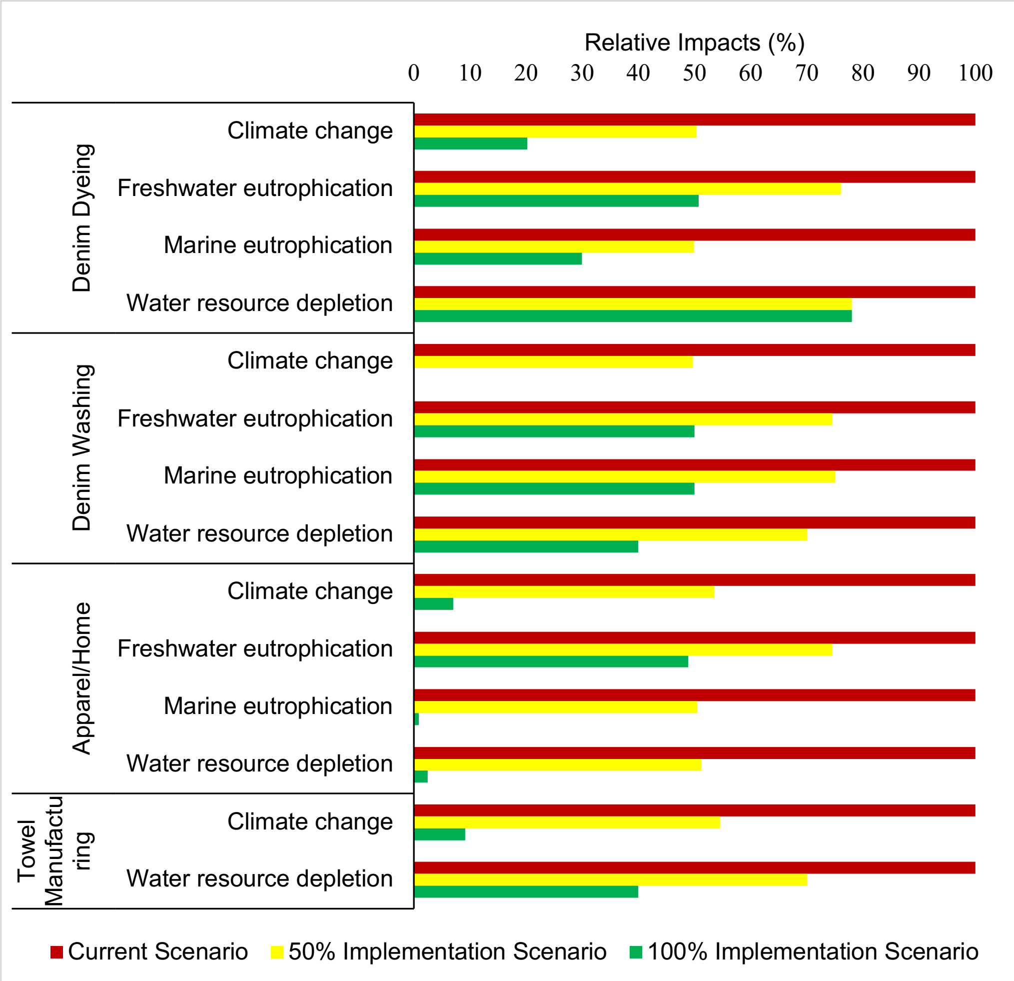

Fig. 3.15: Comparison of the current scenario with two other implementation scenarios in four types of industries

In the case of the 100% implementation scenario, climate change impact further lessened due to the proper treatment of wastewater and the utilization of CO_2 emissions in pH stabilization. Freshwater eutrophication, measured in terms of total phosphorus discharge, showed that its impact reduced completely after the treatment of wastewater. Similarly, marine eutrophication, measured in terms of total nitrogen discharge, was 29.97%, 49.99%, and 0.91% in denim dyeing, denim washing and apparel/home industries, respectively, after the 100% implementation scenario. The water resource depletion was made by the quantification of freshwater used for processing. In the 50% implementation scenario, it was considered that industry had been reusing half of its water reclamation capacity, while in the 100% implementation scenario, the real water reusing capacity was considered.

3.4.3 Selection of different implementation scenarios and estimation of wastewater generation

After auditing and reviewing environmental management plans of wet-processing textile industries, the currently existing environmental status in most of the KITE sector (current scenario) was compared with the best environmental management practices being adopted by a few textile industries. The best wastewater management practices involved the treatment of wastewater, water conservation by subsystem changes, and water reclamation through RO. The current scenario was compared with two different scenarios: 50% implementation of the best management practices followed by 100% implementation of the best management practices (Table 3.9).

Table 3.9: Comparison of different implementation scenarios for the KITE region

Type of industry	Wastewater generation (m^3)	COD (mg/L)	BOD (mg/L)	TSS (mg/L)
Current scenario				
Denim washing	16,623	700	250	750
Denim dyeing	12,331	4,000	1,500	1,200
Apparel/Home	11,209	3,000	900	600
Towel manufacturing	30,798	1,220	290	350
Overall wastewater generation	70,962	1,862	587	630
After 50% implementation of suggestions and recommendations				
Denim washing	11,636	300	130	400
Denim dyeing	8,632	2,000	800	650
Apparel/Home	7,846	1,600	500	320
Towel manufacturing	21,559	700	150	180
Overall wastewater generation	49,673	974	314	335
After 100% implementation of suggestions and recommendations				
Denim washing	6,649	100	30	30
Denim dyeing	4,933	70	15	10
Apparel/Home	4,484	115	26	0
Towel manufacturing	12,319	110	25	20
Overall wastewater generation	28,385	101	25	17

Current Scenario

The current scenario exhibits the condition where the wastewater from the industries is discharged untreated into the Arabian Sea. In this case, the overall wastewater generation by the sector was estimated to be 70,962 m^3/day, and the overall COD, BOD, and TSS concentrations in the effluents at 1,862 mg/L, 587 mg/L, and 630 mg/L, respectively.

50% Implementation Scenario

The 50% implementation scenario estimates the reduction in wastewater after half of all the water-intensive textile industries adopt the best water management practices as they are being performed by the audited industries in the KITE area. The subsystem changes include the reuse of prewash water at the post-wash step, recovery of caustic soda, installation of flow meters and level sensors, and pH neutralization of wastewater by introducing boiler emissions in the wastewater. The wastewater generation could be limited to 49,673 m^3/day after 50% implementation of subsystem changes and component addition options suggested to each type of industry in the previous section.

100% Implementation Scenario

The 100% implementation scenario assumes that all the textile processing facilities in the KITE region adopt all the recommended suggestions. The wastewater generation can be further reduced to 28,385 m^3/day after the 100% implementation of the subsystem changes and component addition options. Furthermore, the COD, BOD, and TSS would fall within the permissible limits under NEQS guidelines through implementing the suggested practices.

3.4.4 Site selection for a combined effluent treatment plant (CETP)

3.4.4.1 Suitable sites

Based on the criteria defined in Section 2.3.3., weighted overlay analysis was done to identify the appropriate sites. The results were categorized into three classes according to the suitability, presented in Table 3.10 and Fig. 3.16. Suitable areas were overlaid with LULC to check if these areas lie in an open field or agricultural area (Table 3.11, Fig. 3.17).

Table 3.10: Area of different suitability categories for CETP

S. No.	Suitability	Area (km^2)
1	High	9.7
2	Moderate	82.6
3	Poor	0.27

Table 3.11: Suitable areas according to LULC

S. No.	Suitability	LULC	Area (km^2)
1	High	Open land area	5
2	High	Agriculture	6.5
3	Moderate	Open land area	9.2
4	Moderate	Agriculture	0.5

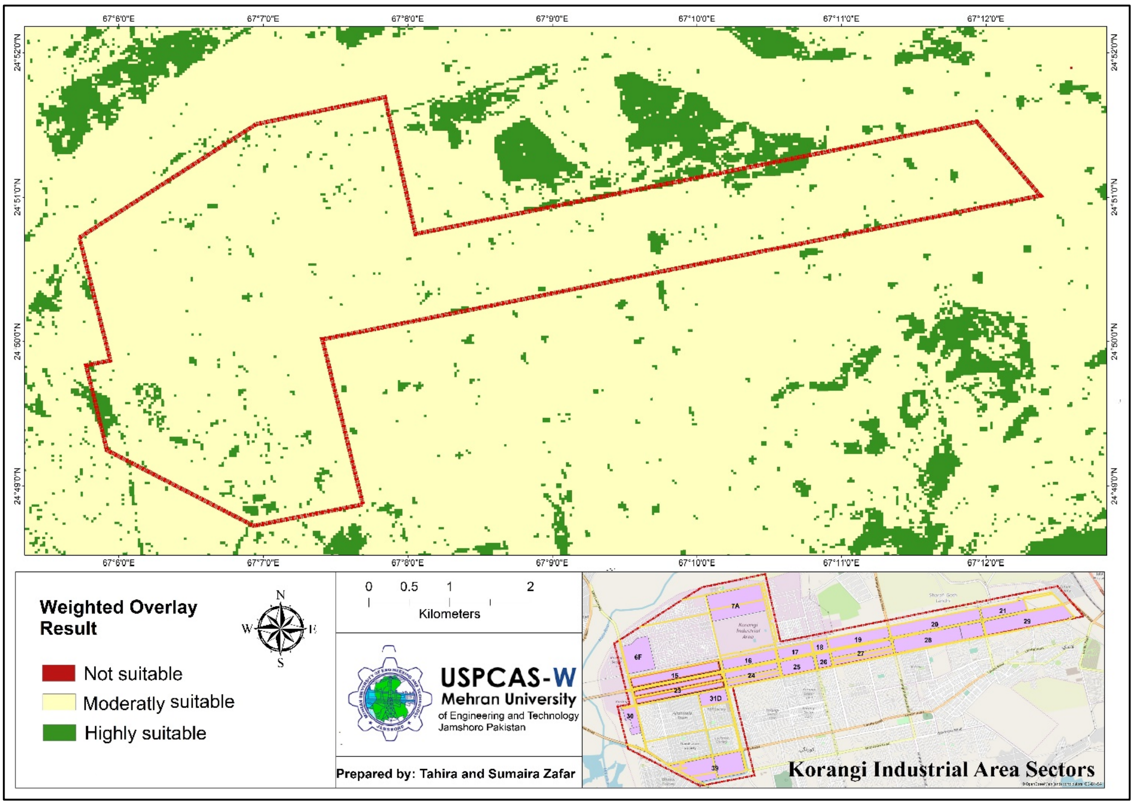

Fig. 3.16: Suitable sites - weighted overlay analysis

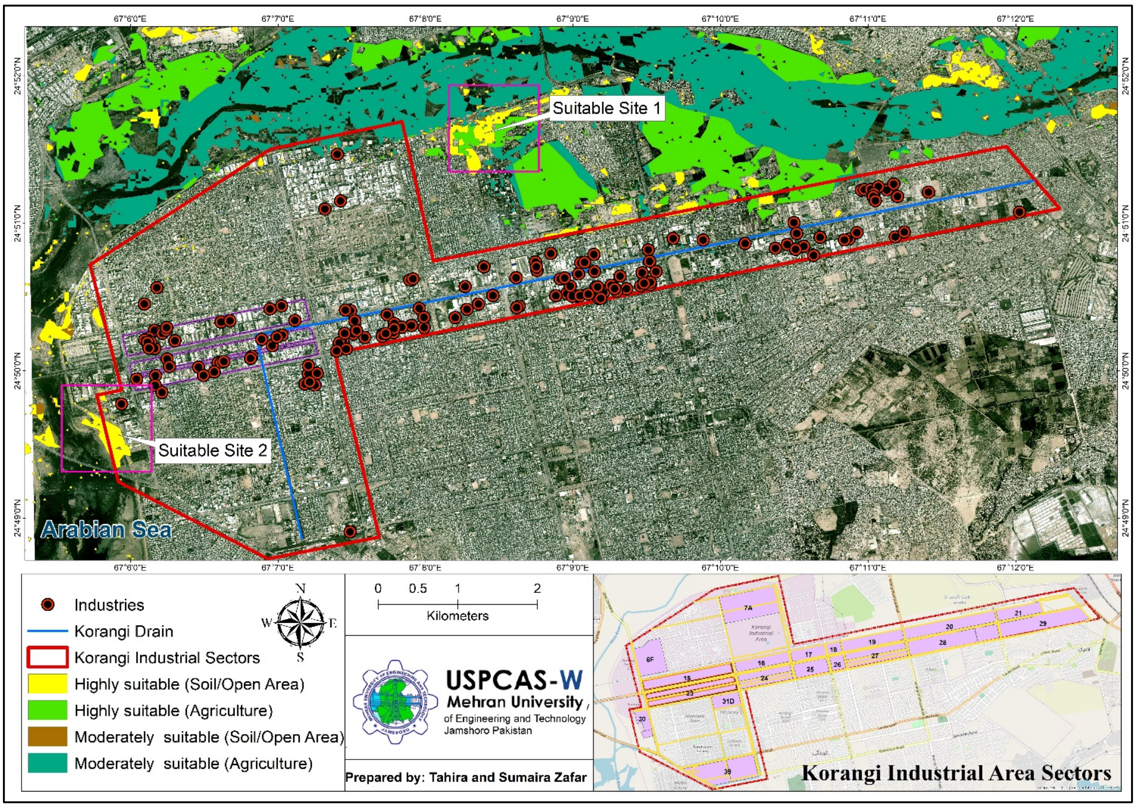

Fig. 3.17: Suitable sites based on LULC

Two sites highlighted in Fig. 3.17 could be the most suitable sites for CETP. Site 1 is located near the bed of the Malir River, and Site 2 is located near the mouth of the Malir River; both areas are fragile ecosystems.

Site 1 is in the north of the industrial sector. This site mainly consists of agriculture and open land area. However, the construction cost for this site will be much higher than that of Site 2. The piping network will be passing through the urban area and will need significant excavation work and permissions from different departments. It will also affect residential neighbourhoods.

Site 2 is located on the western side of the industrial sector near the mouth of the Malir River. This site mainly consists of open fields, but it has a fragile ecosystem (Malir River entering the Arabian Sea). This site is suitable in terms of less construction work; piping work can be done along the roads and will follow the natural gradient. This site has an area equal to the existing CETP for Sector 7A (59,000 m^2).

The sites selected for CETP lie in the lowest elevation area (Fig. 3.18), which will reduce the cost of excavation and other related civil works to maintain the water flow (Fig. 3.19).

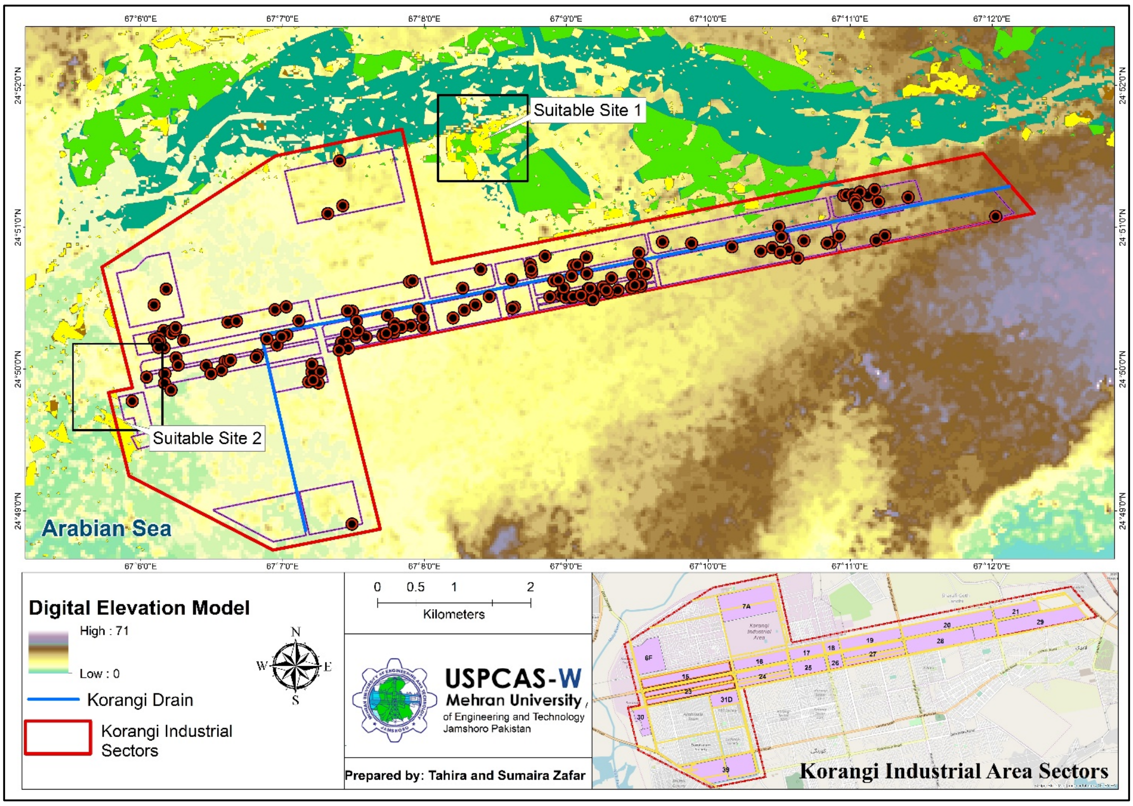

Fig. 3.18: Suitable sites according to site elevation

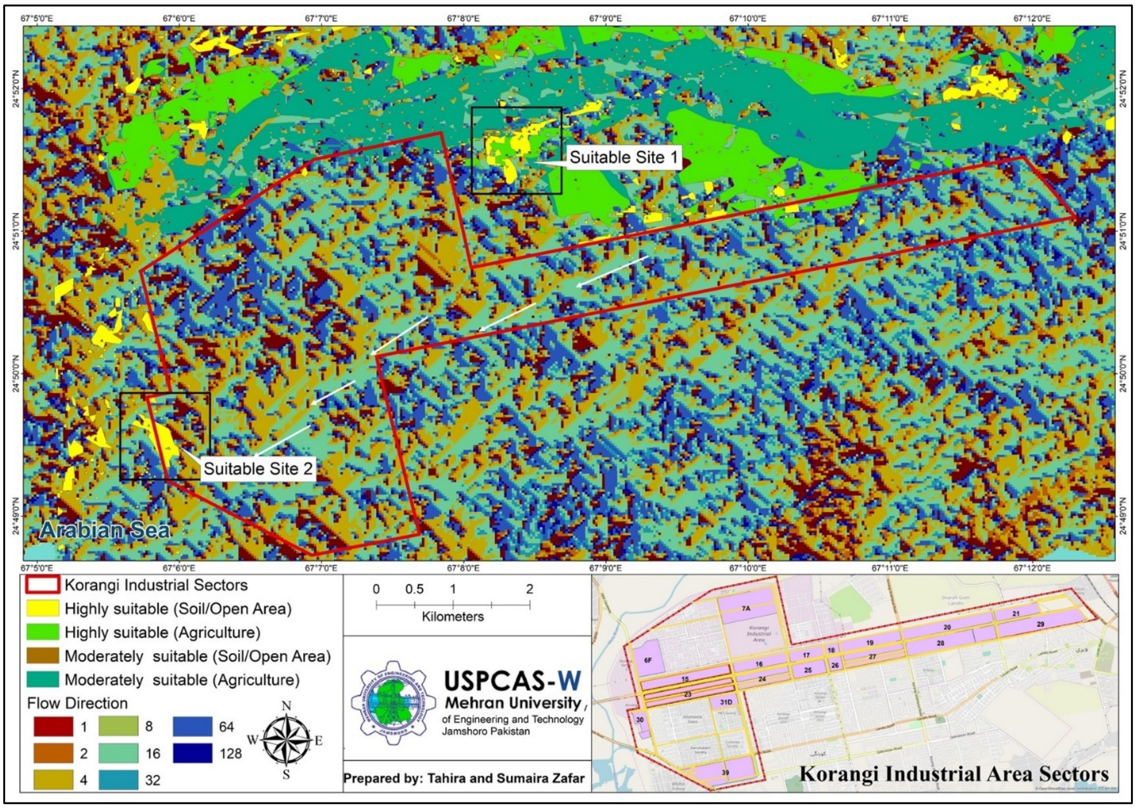

Fig. 3.19: Suitable sites according to the site flow direction

3.5 Research Output

The research output is narrated below in terms of M.Sc. thesis completion by contributing students, poster presentations by students inside and outside of the center, arrangements of focus group discussion for enhancing the capabilities of industrial personnel, and organization of seminars for disseminating the results to the stakeholders.

3.5.1 Poster presentations

1. Channa, A., and Ahmed, Z. (2019). Treatment of indigo dye effluent using anaerobic-anoxic/ aerobic membrane bioreactor. Poster presented on the Earth Day held on April 22 at USPCASW, MUET Jamshoro.
2. Bhutto, F., Ahmed, Z., (2019). Development of integrated sand filtration and microfiltration system for the removal of indigo dye for textile effluent. Poster presented on the Earth Day held on April 22 at USPCASW, MUET Jamshoro.

3.5.2 Research papers

Based on this study, a research paper is being written on the following topic:

- Treatment of indigo dye effluent using anaerobic-anoxic/aerobic membrane bioreactor.

3.5.3 M.Sc. thesis

One M.S student has completed her research work as a part of the project. Name of the student with the title of the thesis is mentioned below:

Aqsa Channa: Treatment of indigo dye effluent using anaerobic-anoxic/ aerobic membrane bioreactor.

3.5.4 Focus group discussions (FGDs)

Throughout the project, four focus group discussions (FGDs) were organized. The dates and venues of the FDGs have already been mentioned in Table 2.2.

3.5.5 Project results dissemination seminars

The project results were disseminated by organizing two seminars, first one at Karachi on September 24, 2019, and the other at the US-Pak Center for Advanced Studies in Water (USPCAS-W), MUET Jamshoro on September 27, 2019. The title of these seminars was: Eco-Innovation in Textile Processing Industries for Sustainable Product Processing.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Existing-in-place and potential eco-innovation options were explored for sustainable product processing within the textile industry in the KITE region in Karachi. For this purpose, surveys, interviews, seminars and focus group discussions were conducted. The surveys and interviews revealed 51 wet-processing and 98 dry-processing units in the industrial sector. During the seminars and FGDs, the essential need for greater industry-academia collaboration and participation of academia, civil society and government bodies for the industrial wastewater management were emphasized upon. Moreover, the responsibility of the wastewater treatment and discharge was laid upon the industrial units.

Four subtypes of industrial units, i.e. denim washing, denim dyeing, apparel/home textiles, and towel dyeing, were selected from the wet-processing units to study the existing and potential eco-innovation options. In the denim washing unit, the following options were found feasible to implement for water & energy conservation and recovery:

1. The flash steam generated could be recovered and utilized in heating the boiler feedwater,
2. The thermodynamic steam traps could be replaced with ball-floating-type steam traps,
3. The exhaust waste heat from dryers could be used for preheating to save energy.
4. Other potential options included, enhancement of the rate of recovery of RO treatment, reuse of RO reject in toilet flushing, recycling of used water from hydro-extraction to the initial washing processes, and condensation of vapors from dried fabric/garments and its reuse.

The audited unit had employed measures for saving water and energy. The maximum water-saving washing process saved up to 100% water compared to a particular conventional process, as it used zero water.

For the denim-dyeing unit, in addition to options as mentioned above, treatment of wastewater using anaerobic-aerobic membrane bioreactor and a filtration system are suggested. Moreover, indigo dye recovery, waste heat recovery, condensate water recovery and end-of-pipe treatment were employed as waste minimization and conservation measures.

The facility audited in the current study had employed a closed-loop system, in which the fabric was being recycled into yarn to be used as a raw material in place of cotton after use. The review of the existing environmental management program at the apparel textiles unit revealed optimized water-use efficiency, on-site water recycling and reuse, waste heat recovery system, caustic soda recovery, and end-of-pipe treatment. Lastly, the towel dyeing unit had employed a waste heat recovery system for steam production with 30% of the total steam capacity, as well as for heating the process water, saving up to 10% of energy for heating. The water consumption was reduced by 18% by undertaking different measures, including wastewater treatment and reuse. The recommendations for the towel dyeing unit included the installation of a caustic recovery plant, the substitution of micron filters with ultrafiltration membranes and of PAC coagulant with alum, and sieve filtration during cone-drying.

Life Cycle Assessment was performed using a software, SimaPro, to evaluate potential environmental impacts of a product or process during its entire life stages. Two implementation scenarios were generated, which depicted 50% and 100% implementation of subsystem changes and component addition options, and were compared with the current scenario, assumed to have no wastewater treatment, reuse or recycle, or ecological damage prevention measures. The 50% and 100% implementation scenarios projected the wastewater generation of approximately 50,000 and 28,400 m^3/d, respectively, a reduction from an estimated 71,000 m^3/d.

A suitable site for a combined effluent treatment plant for the KITE region was identified using a weighted overlay analysis. Two sites were shortlisted. The first site was located in the north of the industrial sector and comprised of partly agriculture and partly open areas. The second site was an open area in the west of the industrial area but was located near the mouth of the Malir River and had a fragile ecosystem. This site was found to be more suitable in terms of convenience in construction and area required.

The environmental problems persistent in the industrial area and their potential solutions were broadly categorized into three groups. An environmental management plan (EMP) was developed to achieve the desired goals and pave the way for future enhancements and better management. The proposed EMP provides specific recommendations for water supply and conservation, wastewater treatment, and adoption of eco-innovation options. The committee overlooking the activities taking place in the KITE region would consist of industry representatives, government officials, water and sewerage services providing agencies, academia, and civil society and community. The roles and responsibilities of each of the stakeholders were defined and described.

4.2 Recommendations

4.2.1 Development of environmental management plan (EMP)

The environmental problems persistent in KITE and their potential solutions can be categorized into three broad areas as given below.

i. Water supply and distribution

The industrial sector relies heavily on the provision of freshwater to carry out processes for manufacturing and other routine operations. However, it has to compete with other water-consuming sectors in the country for the scarce resource. A shortfall to the water demand is thus created as a result of water distribution among various sectors in the country with a burgeoning population and a growing economy. Moreover, problems such as poor governance and infrastructure, and black markets make it increasingly difficult for the industries to meet their freshwater needs. KITE, like other industrial estates and water-consuming sectors, also faces problems as the gap between the supply of and demand for water has widened. According to industrialists, the average demand for freshwater is 800 MGD of which they get around 650 MGD. There are three sources of water from where the industrial sector gets freshwater: (i) KWSB, (ii) Groundwater extraction (iii) Private water supply network/tankers.

a. KWSB

The responsible agency to provide water to the industrial units in the KITE is KWSB. It provides around 650 MGD of water to the Karachi City through the water supply network, leaving a shortfall of approximately 150 MGD. The industrialists rely on two sources of fresh water when dealing with shortages, i.e., groundwater extraction and water tankers or informal water supply. Several areas can be improved to provide enough water to industrial sectors to meet their needs. Firstly, illegal and informal connections should be removed so that everyone gets their due share, and the water resource is paid for. Secondly, a metering system should be introduced by which all the consumers should be charged according to the quantity of water they use rather than the area occupied by the industrial unit. Thirdly, a systematic water pricing method should be developed, and tariffs introduced. Currently, water has been made a cheap resource that is exploited by everyone. A higher water price will not only act as an incentive to adopt water-saving methods and eco-innovation options in industrial operations but also increase revenues of KWSB due to which the organization will be able to operate more efficiently. The water price for starters should at least be made equal to that charged by private water tankers until a comprehensive water pricing system is developed. Lastly, the old water supply network should be gradually replaced with new pipes to reduce system losses.

b. Groundwater extraction

When the water demand is not met from the water supply network by KWSB, industrialists turn towards groundwater as a source. As Karachi is a coastal city, the groundwater is saline, usually containing more than 10,000 mg/L of total dissolved solids, as reported by some of the industrialists. The high salt content of the groundwater makes it unsuitable to be used directly in textile processes. Hence, almost all the large-scale industrial units have on-site RO-based water desalination plants. The estimated operating cost of RO plants is about 60 paisa/gallon, depending on the size of the RO plant, excluding the cost of membrane replacement. If membrane replacement is also accounted for, the overall operations and maintenance cost of the RO system becomes much higher than the cost of fresh water supply from KWSB.

Moreover, the RO systems generate large quantities of reject water (about 30% of feedwater), containing high salt content of up to 35,000 mg/L. This reject water usually drains in the mixed stream of the effluent wastewater from the industrial processes, and eventually ends up in a water body, contributing its role in environmental degradation. Generally, the practice of desalination is cost-intensive, energy-intensive and environmentally unfriendly.

c. Water supply from tankers/informal water supply operators

The third source of water for the industrial sector is the private water tankers or informal water supply network installed and operated illegally by unauthorized persons. Generally, the water supplied by private tankers and informal water supply can be considered brackish (2,000 to 5,000 mg/L of TDS). The quality of water from this source is lower than that supplied by KWSB and that too, with a higher price tag (Rs. 1/gallon). The origin of water supply from both the sources is uncertain. However, the reported sources include the wells on the banks of the Malir River, water taken from drains of Keenjhar Lake, legal hydrants, and from illegal connections from KWSB. This situation has promoted a flourishing “water business” in the industrial sector, which is, however, informal and at times illegal. Currently, the industrialists have no other option to fill the gap between water supply and demand except using private water supply sources. Few of them have expressed their opinion to legalize the private water supply.

ii. Implementation of eco-innovation options

Several eco-innovation options have been identified and discussed earlier in this report. These options require different capital investments ranging from zero to a few million rupees for implementation. However, the environmental returns are high. The large-scale industries have already implemented the majority of these options, which include saving chemicals, energy, and water. The adoption of eco-innovation options by these industries is mainly due to buyers’ pressure. However, medium- and small-scale textile processing industries can also adopt suitable options within their premises and can achieve financial gains together with environmental improvements. However, a few industries face a problem of ending up with a concentrated effluent upon implementation of such options. Regardless, overall benefits are obvious, and dissemination of methods of eco-innovation options need to be promoted.

iii. Installation of a combined effluent treatment plant (CETP)

Despite the implementation of several eco-innovation options, industries, including large-scale units, will still have to deal with the generation of highly polluted wastewater, which must be discharged into water bodies, and ultimately into the Arabian Sea. As per law, the industrial units are required to have wastewater treatment systems inside their facilities before they discharge their wastewater in any drain. This requires them to install wastewater treatment plants. However, the installation of individual wastewater treatment plants is only feasible for large-scale units as they can afford the initial investment and arrange required a land area for the treatment systems. The medium- and small-scale units often do not have the financial might either to install a treatment plant or to keep it running. To counter this problem, we suggest cluster-based CETPs in the KITE area, in which wastewater from the same type of industries will be collected and treated. This will reduce uncertainty in wastewater flow and characteristics. Moreover, as each type of industry generates wastewater with a unique quantity and quality, CETPs for different kinds of industries can be designed according to the specific requirements.

Regardless, if all industries install individual wastewater treatment plants or cluster-based CETPs to meet SEPA standards, the effluent will still need further treatment in a domestic wastewater treatment plant to be finally discharged into a water body. A combined sewage treatment plant, TP4, having a capacity of treating 180 million gallons per day (http://www.kwsb.gos.pk/SitePdfFiles/Flyer.pdf) is part of the KWSB plans. It can be built at a beach adjacent to Pakistan Refinery, at the same location that has been identified in this report earlier in Section 3.4.4. The treatment of both the industrial and domestic wastewater in TP4 has been proposed. Both the Federal and Sindh Government will be financing the treatment plant.

4.2.1.1 Environmental management plan (EMP) committee

To achieve the desired goals and pave the way for future enhancements, improvements, better management and keep the things on track, a board/committee should be made, consisting of all the stakeholders, overlooking all the activities taking place in KITE. Industrialists' representatives, different tiers of government, water and sewerage service-providing agencies, environmental regulatory and monitoring agencies, and academia and civil society should be made part of this committee. The committee will act as a guiding committee for decision-making, problem-solving, fundraising, timely and effective provision of services, technical assistance and socioeconomic aspects. The working of the committee is discussed below, and the corresponding schematic diagram is shown in Fig. 3.20.

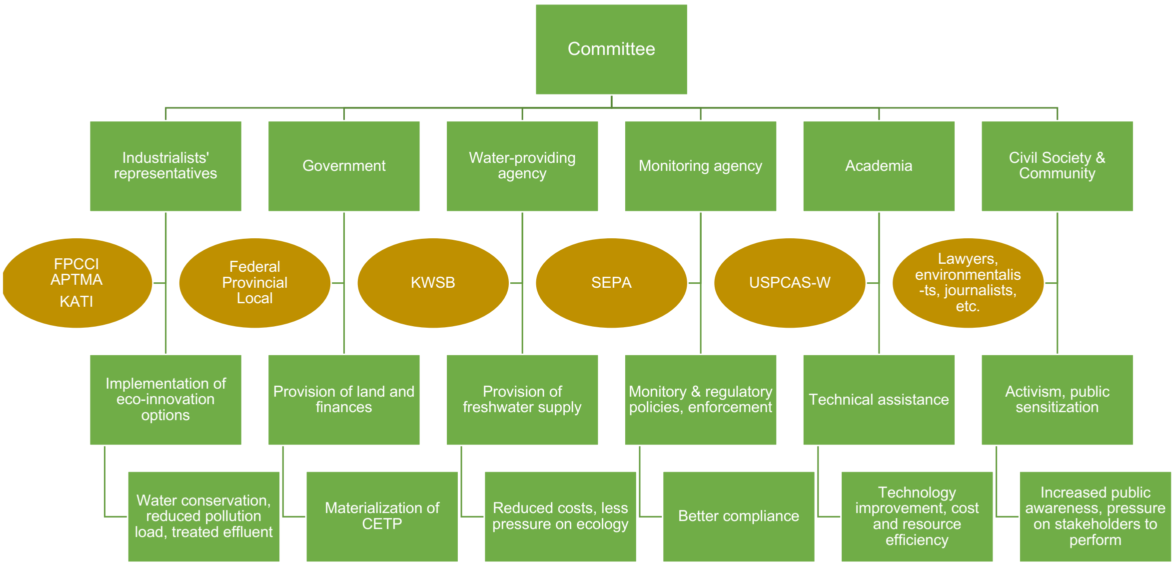

Fig. 3.20: Schematic diagram for the implementation of the environmental management plan

4.2.1.2 Industry representatives

The representatives of the industries will be elected/selected by the industrialists themselves. The representatives will be given the same tenure as that of other committee members. The same representatives cannot be elected more than twice unless approved by the committee. Different industrialists' associations can be a part of the committee, such as FPCCI, APTMA, KATI, etc. They will be responsible for adopting eco-innovation options not only in their industrial units but also throughout the industrial sector. They will advocate for the installation of individual effluent treatment plants in industrial units and environmentally friendly practices.

4.2.1.3 Government

The committee will consist of members from all the tiers of the government, including federal, provincial and local. The government will be requested to provide land and finances for the installation of CETPs. An agreement can also be made with the government to subsidize taxes and customs fees on equipment needed to implement eco-innovation options and CETPs.

4.2.1.4 Water and sewerage services providing agencies

The bodies responsible for delivering water to industries, such as KWSB, will also be made part of the central committee. The KWSB officials will be asked to improve their operations, revamp their infrastructure, introduce a water-metering system and increase the price of water supplied to the industries. They will also be requested to increase the water supply quantity by decreasing system losses, water theft, and removing informal and illegal connections. The KWSB will be directed to form a vigilant team, which will also report to the central committee to prevent any new illegal connections and water theft.

4.2.1.5 Monitoring agency

The representatives from the Sindh Environmental Protection Agency (SEPA) will be responsible for forcing the industrialists to comply with rules and regulations in the law. They will also design and update monitory and regulatory policies in consultation with all the stakeholders.

4.2.1.6 Academia

The industry-academia linkage is already discussed at several places in this report. The academia will help solve the problems faced by the industrialists in inventing, designing and implementing eco-innovation options. The Center for Advanced Studies in Water (USPCAS-W) at MUET, Jamshoro, can play a crucial role in this regard as it has already initiated a long-needed professional relationship with the industrial sector. USPCAS-W can assist the industrialists in technical aspects and provide them with cost-effective solutions, which will not only increase profit margins and protect the environment but also help in building the reputations of industrial organizations.

4.2.1.7 Civil society and community

Members of the civil society and communities living nearby will also be made part of the committee. Lawyers, journalists, environmentalists, activists, and non-governmental organizations will be part of the civil society. This group of stakeholders will act as a pressure group on industrialists, KWSB and the government to implement eco-innovation options, strict monitoring and regulation and a better environment for the residents and wildlife. They will also sensitize the public on environmental issues so that the ecological damages don’t go unnoticed as it happens in the current situation.

REFERENCES

Alasdir, R., and Meidzinski, M. (2008). Eco-innovation Final Report for sectorial innovation watch. Brighton.

Ali, I., Kim, Seu-Run., Kim, Sung-Pil., and Kim, Jong-Oh. (2016): Recycling of textile wastewater with a membrane bioreactor and reverse osmosis plant for sustainable and cleaner production, *Desalination and Water Treatment*, DOI: 10.1080/19443994.2016.1172513

Carrillo-Hermosilla, J., del González, P.R., and Könnölä, T. (2009). Eco-Innovation: When Sustainability and Competitiveness Shake Hands. Palgrave Macmillan UK, pp. 6–27.

Cleaner Production Institute. (2002). Cleaner Technology for Production [Online]. Available: http://www.cpi.org.pk/ProjectCtpTextileEnvEngineering.aspx. [Accessed: 11-Jun-2018].

Goedkop, M. (1995). The Eco-indicator 95. Amsterdam.

Kemp, R., and Pearson, P. (2007). Final Report, MEI project about measuring eco-innovation. Netherlands.

KWSB. http://www.kwsb.gos.pk/SitePdfFiles/Flyer.pdf

Mehmood, S.N., Naeem, S., Siddiqui, I., and Khan, F.A. (1998). Metal contamination in ground water of Korangi industrial area, Karachi. *J. Chem. Soc. Pakistan*, 20(2): 125–131.

Memon, N.A. (2011). Denim industry of Pakistan: New import duty on denim by Turkey. *Pakistan Text. J.*, 60(6): 40–42.

Memon, N.A. (2013). Pakistan textile processing industry facing environmental challenges," *Pakistan Text. J.*, .

OECD. (2010). Eco-Innovation in Industry: Enabling Green Growth. Paris.

Paavola, J. (2007). Institutions and environmental governance: A reconceptualization. *Ecol. Econ.*, 63(1) 93–103.

PAK EPA. (2005). Draft Report 'State of the Environment..

Pré Consultants, B.V. (2018). SimaPro. [Online]. Available: https://simapro.com/. [Accessed: 13-Jan-2018].

Pakistan Tanners Association. (2017). [Online]. Available: http://www.pakistantanners.org/pta_institutions_cetp.html. [Accessed: 11-Jan-2018].

Rahman, A.U., and Sabir, M.I. (2015). Ecological risk assessment of ground water quality of two industrial zones of Karachi, Pakistan. *Br. J. Appl. Sci. Technol.*, 14(2): .

Rashid, L., Yahya, S., Shamee, S.A., Jabar, J., Sedek, M., and Halim, S. (2014). Eco product innovation in search of meaning: Incremental and radical practice for sustainability development. *Asian Soc. Sci.*, 10(13): .

Sahoutara, N. (2017). Karachi water board's failure can lead to an epidemic, SC fears. [Online]. Available: https://tribune.com.pk/story/1351082/karachi-water-boards-failure-can-lead-epidemic-sc-fears/. [Accessed: 11-Jan-2018].

Saleem, M. (2002). Study of heavy metal pollution level and impact on the fauna and flora of the Karachi and Gwadar coast. Karachi.

Stahel, W.R., and Jackson, T. (1993). Optimal utilization and durability. In: *Clean Production Strategies Developing Preventive Environmental Management in the Industrial Economy*, Boca Raton, Florida: Lewis Publishers, pp. 261–291.

Subramani, T., Subramanian, A., Kathirvel, C., and Bharathi Devi, S.K. (2014). Analysis and site suitability evaluation for textile sewage water treatment plant in Salem Corporation, Tamilnadu using remote sensing techniques. *Int J Eng Res Appl.*, 8(6): 90–102.

Vázquez-Rowe, I., Hospido, A., Moreira, M. T., and Feijoo, G. (2012). Best practices in life cycle assessment implementation in fisheries: Improving and broadening environmental assessment for seafood production systems. *Trends in Food Science and Technology*, *28*(2): 116–131. Raton, Florida: Lewis Publishers, 1993, pp. 261–291.

von Hippel, E. (1988). The source of innovation. New York: Oxford university press.

Wenzel, H., Hauschild, M.Z., and Alting, L. (1997). Environmental Assessment of Products. 1. Methodology, Tools, and Case Studies in Product Development. Springer US.

Annexures

Annex 1: Questionnaire form 1 for data collection

Basic information about the industry	
Name	
Address	
Location	
Longitude	
Latitude	
Major Products	
Contact person's information	
Name	
Designation	
Contact No.	

Processes and Production information			
a.	**Major Processes involved in the production (Tick all relevant)**		
Spinning	Yarn Dyeing	Sizing	Weaving
Desizing	6(a). Scouring	6(b).Keyring	7. Bleaching
8. Mercerizing	9(a). Dyeing	9(b). Printing	10. Finishing
11. Garment washing	12. Garment/stitching		
b.	**Production capacity information**		
S. No.	**Products manufactured**	**Production capacity**	**Actual Production**
1.			

4- Water/Electricity sources and their consumption			
Water			
a.	Sources and Quantity of water? (Tick all relevant/ m3/day or gallons per day)		
KWSB	Boring	Tankers (no of tankers/d* size)	Tube wells, canals, etc.
b.	Approximate cost of water paid per month? KWSB, Boring , Tanker , ground		
c.	Approximate volume of water consumed per month?		
Electricity			
a.	Maximum demand for electricity per month?		
b.	Fuels used in various purposes/ back-up power?		
Diesel	**Natural Gas**	Any biofuel	Others
c.	Power and Steam Generation Facility		
No. of Steam Boilers		Steam generation capacity/boiler	
No. of Power Turbines/ Generators		Power generation capacity per turbine/Generator	
d.	No. of heat exchangers (Water, Steam, Air)?		
e.	Details of compressors		
Number	Type	Capacity	

The volume of water consumed in gallons/kg or gallons per running meter of various products manufactured in different processes			
1. Spinning	2. Sizing	3. Weaving	4. Desizing
5(a). Scouring	5(b). Keyring	6 Bleaching	7. Mercerizing
8(a). Dyeing	8(b). Colorant	9. Post Dyeing/ Printing washing	10. Chemical/ other Finishing
11. Cooling water	12. Sanitary	13. Fire Fighting Use	14. Other Uses

List of steps taken to conserve water, energy, or chemical?	

Water conservation measures are taken through REUSE?
Reuse of water jet weaving wastewater
Reuse of bleach bath
Recovery of condensate
Reuse wash water/ Rinse water
Heat Exchanger
Steam Recovery
Reuse of final rinse water from dyeing for dye bath make-up
Reuse of Scouring Rinses for De-sizing
Reuse of Mercerizing or Bleach Wash
Water for Scouring or De-sizing
Reuse of soaper wastewater
Reuse of dye liquors
Reuse of cooling water
Others

Are other measures taken for water conservation?
Use of automatic shut-off valves
Use of flow control valves
Flocculation of clean water of pigment printing
Use a single stage of processing
Use of low material to liquor ratio systems
Water conservation measures in dyeing equipment
Proper insulation of the steam lines
Other

Materials used in processes			
	Which textile materials are being used? (Tick the relevant)		
Cotton	Wool	Nylon	Rayon
Polyester	Acrylic		
b.	Are you familiar with green dyes and auxiliaries?		
c.	Have you ever thought of replacing harmful azo dyes with synthesis ecofriendly dyes?		

Water and Wastewater treatment		
a.	Water treatment (Ion-exchange, Filtration, RO, etc.) Please state capacity and usage	
b.	Do you have Effluent Treatment Plant (ETP) in your establishment? If yes, please provide details?	
c.	Does all waste streams from various processes treated separately? If yes, provide details in column c1	
Yes		No
C1		

Energy and environmental audits			
a.	Have you ever checked your system efficiency through integrated Energy and environmental audit?		
Yes		No	
b.	If yes, have you considered/implemented the suggested options?		
No cost	Low cost	High cost	
c.	Which limitations have you encountered in implementing?		
Technical	Lack of Expertise/ Skills	Finances	
d.	Licensing/Registration/ Certification		

NOC from EPA	Yes
Reason (if not compliant)	
Other Certifications/Registrations	

13- Suggestions to conserve water and energy

Annex 2: Questionnaire form 2 for data collection

Name of the factory: ____

Type: ________________________

Address: ____

1. Staff costs
i. Number of personnel:
ii. Number of personnel at the wastewater treatment plant:
iii. Total salary of the personnel at the WWTP:
2. Water and wastewater characteristics
i. Freshwater consumed:
ii. Freshwater cost:
iii. Water reuse (if any):
iv. Wastewater generated:
v. Sludge disposal mechanism:
vi. Existing wastewater treatment system:
vii. Existing treatment efficiency:
a. % COD removal:
b. % TSS removal:
c. % Nutrient removal:
3. Operational costs
i. Chemicals required:
ii. Chemical consumption:
iii. Costs of chemicals:
iv. Energy consumption:
v. Energy consumption per m^3 of wastewater treated:
vi. Cost of energy:
4. Maintenance costs
☐ Equipment replacement cost:
☐ Equipment repairment cost:
☐ Labor cost:
5. Greenhouse gas emissions:
i. Indirect emissions from energy use:
ii. Direct emissions from wastewater

Freshwater characteristics

Influent freshwater characteristics		Influent reuse-water characteristics	
Parameter	Concentration	Parameter	Concentration
pH		pH	
Turbidity (NTU)		Turbidity (NTU)	
TDS (mg/L)		TDS (mg/L)	
Alkalinity (mg/L)		Alkalinity (mg/L)	
Nitrate (mg/L)		Nitrate (mg/L)	

Wastewater characteristics

Wastewater characteristics		Treated wastewater characteristics	
Parameter	Concentration	Parameter	Concentration
pH		pH	
Color		Color	
TDS (mg/L)		TDS (mg/L)	
COD (mg/L)		COD (mg/L)	
sCOD (mg/L)		sCOD (mg/L)	
BOD (mg/L)		BOD (mg/L)	
sBOD (mg/L)		sBOD (mg/L)	
VSS (mg/L)		VSS (mg/L)	
TSS (mg/L)		TSS (mg/L)	
Total Nitrogen (mg/L)		Total Nitrogen (mg/L)	
Ammonia (mg/L)		Ammonia (mg/L)	
Organic Nitrogen (mg/L)		Organic Nitrogen (mg/L)	
Total Phosphorous (mg/L)		Total Phosphorous (mg/L)	

Existing environmental interventions with industries

Improved Area	Improved method	Project Description	Saving	Total Cost	Pay Back Period
Water Usage					
Energy					
Wastewater treatment					
Air					
Any Other					

Annex 3: List of textile industries located during the survey with latitude and longitude

S No.	Name of textile industry	Type of industry	Sector	Plot No.	Logitude	Latitude
1	Artistic Garment Industries Pvt Ltd (K-1)	Denim Fabrics / Garments	Sector-15	60	67.1185744	24.839
2	Qamar Brother & Sons Pakistan (Pvt.) Ltd	No information/website	Sector-15	33/1	67.1027483	24.8359
3	Carisons Industries (Pvt) Ltd	high-quality printing	Sector-15	3-/7	67.1021261	24.8371
4	Hayat Trading & Industrial Int.	home textiles	Sector-15	33/4	67.1022551	24.8366
5	Jawaid Bross Label Industry Pvt. Ltd.	Knitting, Dyeing, Fabric & apparel	Sector-15	2/5	67.1036592	24.8378
6	Lakhani Apparel	No information/website	Sector-15	2-/4	67.1016196	24.8368
7	Marfani Denim Mills	Denim	Sector-15	26	67.115775	24.8403
8	Naseem Apparels	apparels	Sector-15	37/3	67.1050315	24.8367
9	Sunflower Industries	Knitting, Cutting , Stichting	Sector-15	28/1	67.1170841	24.8407
10	Syncotex Agencies	febric, Cotton, Polyester	Sector-15	32/7	67.1020484	24.8362
11	Syntech Fibres Pvt Ltd	polypropylene fibres and yarns	Sector-15	5/3--	67.1036259	24.8376
12	The Apparel Source	apparel	Sector-15	6/2 --	67.103833	24.8379
13	Umar Textiles	Towels and home textile	Sector-15	51/6		
14	Unitex Private Limited	Textile Products & Machinery	Sector-15	4/1---		
15	Universal Fashions Pvt Ltd	Leather, Knit	Sector-15	32/4	67.1019438	24.8366
16	Van Louis	home supplies, towels	Sector-15	126		

S No.	Name of textile industry	Type of industry	Sector	Plot No.	Logitude	Latitude
17	Vista Apparels	Apparel manufacturing	Sector-15	1/6	67.1040979	24.8382
18	Weave & Knit Pvt Ltd	Garments	Sector-15	152		
19	Zora Knit	Knitting	Sector-15	33/9	67.1020922	24.8359
20	Artistic Denim Mills Ltd	Apparel manufacturing	Sector-16	7,8,9 & 26	67.1248806	24.8401
21	DSI Pakistan Pvt Ltd	clothes, shoes		11/10--		
22	IBC Apparel Limited	Apparel manufacturing	Sector-16	C-1/13	67.1315694	24.8436
23	Kings Apparel Industries Pvt Ltd	No information/website	Sector-16	22	67.1242917	24.8402
24	Swano Enterprise	No information/website	Sector-16	CIB-14	67.1319223	24.8437
25	Asacotex	cutting age	Sector-17	10/1--	67.139935	24.8451
26	International Textile Limited	home textiles, cotton bleaching & dyeing	Sector-17	16	67.1378288	24.8429
27	Silver Textile Factory	No information/website	Sector-18	ST-2	67.1435805	24.8439
28	Al Ameen Trading Corportation (Pvt) Ltd	Knitting	Sector-19	28	67.1508667	24.8455
29	Al Fazal Textiles	No information/website	Sector-19	29	67.151313	24.8456
30	Rajby Industries Washing & Finishing Unit	Washing & Finishing	Sector-19		67.1523667	24.8465
31	Junaid Jamshed (Pvt.) Ltd	Garments	Sector-19	ST-2/12	67.1585113	24.847

S No.	Name of textile industry	Type of industry	Sector	Plot No.	Logitude	Latitude
32	Gul Ahmed Textile	Garments	Sector-19	SC-6, Street1	67.1457675	24.8456
33	Orient	Garments	Sector-19		67.1475056	24.8466
34	Harm Industries		Sector-19	SC-6, Street1	67.1459327	24.8447
35	Denim Clothing Company	Denim	Sector-19	SC-7, Street1	67.1458679	24.8451
36	Artistic Milliners AM-6 Unit	Garments	Sector-20		67.161304	24.8483
37	International textile Ltd	manufacturer of high-quality Towels, & Textile made-ups	Sector-20		67.1749726	24.8501
38	Owais Cone Dyeing	Dyeing	Sector-21	Plot-4/19	67.1866843	24.853
39	Tamachi Weaving Pvt Ltd	weaving	Sector-21	3/6	67.1854575	24.8538
40	RZ Bleaching	Dyeing	Sector-21		67.1825828	24.8538
41	Rahman Towels	Towel	Sector-21		67.1829185	24.8538
42	Hassan Jamal Threads	No information/website	Sector-21		67.1836393	24.8538
43	Khadija Mills	No information/website	Sector-21		67.1845038	24.8542
44	SS Dying	Dyeing	Sector-21		67.1839989	24.8534
45	Fabrica	No information/website	Sector-21		67.1839214	24.8531
46	MNN Knitting	Knitting	Sector-21		67.1841612	24.8526
47	Norani Dyeing	Dyeing	Sector-21		67.1862355	24.8545

S No.	Name of textile industry	Type of industry	Sector	Plot No.	Logitude	Latitude
48	Artistic Garment Industry Unit K13	Garments	Sector-21		67.1901602	24.8535
49	Admiral (Pvt) Ltd	No information/website	Sector-23	23/1	67.1148208	24.8369
50	Soorty Enterprises Pvt Ltd Unit 1,2 & 3	Garments	Sector-23	24/1	67.1165583	24.8371
51	Akhtar Textile Industries Pvt Ltd	Manufactures and exports garments (such as denim jeans, khakis, and casual trousers)	Sector-23	5	67.1041413	24.8347
52	AL-Aamir Pvt Ltd	Hosiery and Knitwear Garments	Sector-23	149	67.1028386	24.8328
53	Al-Merah Apparel Pvt Ltd	knitting Apparel	Sector-23	27	67.1171507	24.8374
54	Ali Murtaza Associates (Pvt) Ltd	Apparel manufacturing	Sector-23	186	67.1137372	24.835
55	Amir Industries	towels and cotton	Sector-23	172-173	67.1099206	24.8343
56	Anis Apparel	Apparel manufacturing	Sector-23	165-166	67.107691	24.8337
57	B. K. Saddam (Pvt) Ltd.	No information/website	Sector-23	122-123	67.1160155	24.8362
58	Fashion Channel Pvt Ltd	Garments	Sector-23	185	67.1135837	24.8347
59	Four Season Garments	Garments	Sector-23	174	67.1102819	24.8343
60	Gajiani Textile	No information/website	Sector-23	15		
61	Good Luck Industries	No information/website	Sector-23	216/1	67.1082614	24.8328
62	Kamran Knit	No information/website	Sector-23	19		
63	Prestige Apparel	No information/website	Sector-23	48	67.1043977	24.8338

S No.	Name of textile industry	Type of industry	Sector	Plot No.	Logitude	Latitude
64	Tex World	Manufacturers & Exporters of High Quality Design & Fashion Towels	Sector-23	146-A	67.1006932	24.8324
65	Texmat Industries Pvt Ltd	No information/website	Sector-23	175	67.1105546	24.8344
66	U.F.T. Corporation	No information/website	Sector-23	208		
67	Unicon International (Pvt) Ltd.	embroidered fabric manufacturers	Sector-23	207	67.1028037	24.8317
68	Soorty Enterprises Pvt Ltd Unit 1,2 & 3	Garments	Sector-23	26	67.1165583	24.8371
69	Afraz Knit & Stitch	knitting	Sector-24	157	67.133197	24.8382
70	Al-Khair HMD Industries (Pvt) Ltd	No information/website	Sector-24	169-170	67.1264722	24.8371
71	Bonanza Garment Industries (Pvt) Ltd.	Garments, stitching	Sector-24	17/1	67.1326289	24.8404
72	Contenental Apparels	Garment Manufacture	Sector-24	205	67.129724	24.8376
73	Creative Knits	Apparel manufacturing	Sector-24	62	67.125178	24.8375
74	Crescent Enterprises	knitting and woven	Sector-24	227	67.124024	24.8366
75	GIA Associates Pvt Ltd	No information/website	Sector-24	18	67.133172	24.8394
76	Hasham Towel	Weaving,Dyeing,stitching	Sector-24	126	67.128507	24.8374
77	J.B.Industries	No information/website	Sector-24	11	67.1289996	24.8397
78	Multifab Pvt.Ltd.	No information/website	Sector-24	84	67.1317541	24.8385

S No.	Name of textile industry	Type of industry	Sector	Plot No.	Logitude	Latitude
79	Nutex International Pvt Ltd	No information/website	Sector-24	93-94	67.123596	24.8365
80	Quality Dyeing & Finishing (Pvt) Ltd.	Dyeing and Finishing	Sector-24	42	67.129828	24.8387
81	Shahzad Apparel	apparel	Sector-24	80	67.130651	24.8383
82	Excel Tex Industries	No information/website	Sector-24	235	67.124385	24.8358
83	Artistic Garment U#7	No information/website	Sector-24	5	67.1253541	24.839
84	Unique Packages	packaging and services	Sector-24	233/1	67.123304	24.8356
85	Zafar Industries		Sector-24	19		
86	Noor Pur industries	Manufacture Terry Towels and Bathrobes	Sector-24	78	67.1297989	24.8381
87	Textile Fort		Sector-24	65	67.124214	24.8376
88	Brand Roots Industries		Sector-24	61	67.125558	24.8379
89	Ma Sha Allah Denim	Denim	Sector-24		67.128456	24.8372
90	Unique Embroidery		Sector-24		67.128853	24.8375
91	Ali Asghar Textile Mills Limited	Spinning	Sector-25	2 & 6	67.1366918	24.8394
92	Artistic Apparels (Pvt) Ltd	Garments	Sector-25	4	67.1409455	24.8418
93	Artistic Milliners Pvt.Ltd.	Garments	Sector-25	8	67.139326	24.8409
94	Indus Dyeing & Manufacturing Company Ltd	Dyeing	Sector-25	3&7	67.1380231	24.8403
95	Kamran & Brother	woven fabrics	Sector-26	13-14	67.1439145	24.8406
96	Texknit	knitting	Sector-26	14	67.1436487	24.8405

S No.	Name of textile industry	Type of industry	Sector	Plot No.	Logitude	Latitude
97	A. Majeed & Sons	Dyeing & Bleaching	Sector-27	88	67.1493132	24.8421
98	Al-Hamra Industries		Sector-27	294		
99	Asmat Textile Industries	No information/website	Sector-27	262	67.153451	24.8422
100	Bilal Towel	towel	Sector-27	99	67.152596	24.8428
101	Designs International	home supplies, towels	Sector-27	14	67.150635	24.8443
102	Syntax		Sector-27	143	67.1504365	24.8418
103	Fortune Export International	home supplies, towels, blankets	Sector-27	188	67.158763	24.8431
104	Habib Knit Fabrics Pvt Ltd	knitting, yarn dyeing	Sector-27	80A,B&C	67.15939	24.8445
105	Haleema Apparal	Apparel manufacturing	Sector-27	146	67.1499389	24.8418
106	J. Sons Textiles	Terry Towel, Terry Bathrobe	Sector-27	120	67.1496889	24.8429
107	M. Y. Towel	Towel bleaching dyeing	Sector-27	9	67.1576574	24.8429
108	Mehran Thread Works	Thread	Sector-27	7	67.1485511	24.8437
109	Pearl Fabrics Company	towel (Dyeing & Weaving)	Sector-27	40-A	67.1586545	24.8457
110	Pearl Fabrics Corporation	No information/website	Sector-27	20	67.1524194	24.8446
111	Polytex International	yarn Manufacturing	Sector-27	69	67.1553225	24.844
112	Rajby Industries H/O & Unit-2	Garments	Sector-27	38-39	67.1578056	24.8444
113	Rajby Industries Washing & Finishing Uni	Washing & Finishing	Sector-27	149	67.1507971	24.8418
114	Rizwan Industries	preparatory, weaving,stitching	Sector-27	105	67.154338	24.843
115	Rizwan International (Pvt) Ltd	towel & cotton	Sector-27	62	67.1587323	24.8433

S No.	Name of textile industry	Type of industry	Sector	Plot No.	Logitude	Latitude
116	Hope Garment	Garments	Sector-27	307	67.1529346	24.8415
117	Abdullah Fabrics	No information/website	Sector-27	170	67.1560608	24.8426
118	Moazzam Silk	Silk Manufacturing	Sector-27	162	67.1549096	24.8423
119	Denim-e	fabric and garments	Sector-27		67.1527983	24.8428
120	Sadaf Brothers	No information/website	Sector-27		67.158045	24.8432
121	Shah Shamsi	No information/website	Sector-27	308	67.153139	24.8415
122	Owais Textile	Garments	Sector-27		67.1517342	24.842
123	K&T Knitting	Knitting	Sector-27		67.1480648	24.8418
124	Rajby Unit 1	Garments	Sector-27		67.1490635	24.8438
125	Golden Industries	No information/website	Sector-27	122	67.1547059	24.8426
126	Denim International	Garments	Sector-28	48	67.1760955	24.8474
127	Grace Apparel (Pvt) Ltd	Apparel manufacturing	Sector-28	27	67.1742026	24.8476
128	Grace Knitwear (Pvt) Ltd.	Apparel manufacturing	Sector-28	46	67.1751571	24.8471
129	HAMSONS INDUSTRIES	No information/website	Sector-28	54-B	67.181182	24.8482
130	Naveena Exports Ltd	Spinning	Sector-28	1 & 2	67.1694517	24.8477
131	Pelikan Knitwear	Garments	Sector-28	67	67.1771955	24.8464
132	Precision Rubber Products Ltd	Textile Accessories	Sector-28	24	67.172865	24.8472
133	International Textile Ltd	No information/website	Sector-28	33	67.1749726	24.8501

S No.	Name of textile industry	Type of industry	Sector	Plot No.	Logitude	Latitude
134	Artistic Garment Industries Unit K2	Garments	Sector-28		67.1806647	24.8481
135	WEAVART	Weaving	Sector-28	11	67.1752793	24.8489
136	Ashraf and Company	Fabric manufacturing	Sector-29	2		
137	Lakhany Silk Mills (Pvt) Ltd.	Silk Manufacturing	Sector-29	21	67.186553	24.848
138	Textilfort Private Limited	Knitting, yarn dyeing	Sector-29	22	67.187553	24.8482
139	Artistic Garment Industries Unit K6	Denum	Sector-29		67.200284	24.8508
140	Umar Garments	Garments stitching	Sector-29	1-B-1	67.182073	24.849
141	Terry Tex Industries	Weaving, Towels	Sector-30	ID-5	67.098996	24.8296
142	Jena Dyeing	Dyeing	Sector-39	228/II	67.124829	24.8151
143	Al-Hamd Industries	No information/website	Sector-31A	C-29	67.103554	24.8309
144	Afetex Industries	Garments	Sector-31D	C-4	67.1197366	24.8318
145	IQ hosiery	hosiery	Sector-31D		67.1202486	24.8321
146	Hajra Textiles	Apparel & fashion	Sector-7A	122	67.123381	24.8578
147	Hamza Textile	sizing , weaving	Sector-7A	82	67.123738	24.8526
148	MIMA Knit (Pvt) Ltd.	knitting	Sector-7A	72	67.12198	24.8516
149	Reliable Towels	Towel	Sector-6F	C-71	67.101565	24.8409

Annex 4: Project results dissemination seminar at Karachi

Annex 5: Project results dissemination seminar at USPCAS-W, MUET, Jamshoro

Annex 6: Pictures taken during focus group discussions

Focus group discussion at FPCCI, Karachi

Focus group discussion at Korangi Association of Trade and Industry (KATI), Karachi

Focus group discussion at Korangi Association of Trade and Industry (KATI), Karachi

Focus group discussion at Zafan Hotels, Karachi

About the Author

Dr. Zubair Ahmed is working as Professor (Environmental Engineering) and Head of Department (HoD) (Environmental Engineering) in U.S.-Pakistan Center for Advanced Studies in Water at Mehran University of Engineering and Technology (MUET), Jamshoro. He did his PhD from University of Science and Technology, South Korea. He has been involved in various studies pertinent to operation of membrane bioreacters (MBRs). He has over 20 years of research experience. During his PhD studies, Dr. Ahmed has utilized sequencing anaerobic/anoxic-aerobic MBRs for removal of nitrogen and phosphorus. He has been involved in execution and supervision of various research projects including development of polymer based adsorbent for aluminum ion in treated water; removal of gaseous toluene using a pure yeast strain; biodegradation of estrogenic compounds in a pre-anoxic/anaerobic nutrient removing membrane bioreactor and different MBR related studies. His work has been published in a number of top ranked peer reviewed journals. Moreover, Dr. Zubair has conducted various environmental impact assessment and audits in different industrial sectors such as petroleum industry, textile industry, and leather industry.

Main thrust of Applied Research component of the Water Center is to stimulate an environment that promotes multi-disciplinary research within the broader context of water-development nexus to support evidence-based policy making in the water sector. This is pursued using the framework provided by the six targets of the Sustainable Development Goal on Water i.e., SDG-6.

Contact:

U.S.-Pakistan Centers for Advanced Studies in Water
Mehran University of Engineering and Technology, Jamshoro-76062, Sindh - Pakistan

92 22 210 9145 water.muet.edu.pk /USPCASW /USPCASW