Assessment and Optimization of Textile Wastewater Management for Environmental Sustainability in India

PhD Thesis

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Assessment and Optimization of Textile Wastewater Management for Environmental Sustainability in India

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November 2019

DECLARATION

I, **Punyasloka Pattnaik**, declare that this thesis titled, "**Assessment and Optimization of Textile Wastewater Management for Environmental Sustainability in India**" and the work presented in it, are my own. I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this university.
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this university or any other institution, this has been clearly stated.
3. Where I have consulted the published work of others, this is always clearly attributed.
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
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CERTIFICATE

This is to certify that the thesis entitled "**Assessment and Optimization of Textile Wastewater Management for Environmental Sustainability in India**" being submitted by **Ms. Punyasloka Pattnaik (2016RBM9047)** is a bonafide research work carried out under my supervision and guidance in fulfillment of the requirement for the award of the degree of **Doctor of Philosophy** in the **Department of Management Studies**, Malaviya National Institute of Technology, Jaipur, India. The matter embodied in this thesis is original and has not been submitted to any other University or Institute for the award of any other degree.

31.10.19

Place: Jaipur
Date:

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Date **Punyasloka Pattnaik**

Place

ABSTRACT

The contribution of the textile industry in India plays a vital role in the economic growth of a nation. The growth of the textile industry not only impacts the economy of a country but also influences the global economy and the mutual exchange of technology between the countries. However, the textile industry also generates an enormous quantity of waste as waste sludge, fibers, and chemically polluted waters. The chemically polluted textile wastewater degrades the quality of the soil and water when mixing with these natural resources and simultaneously depend on the habitats and the environment. Seeing to the existing problem in solid and liquid waste, the textile industries are facing major problem towards the environment pollution. Therefore, the researchers and the textile industries are focusing on the reduction of textile wastewater and the formulation of alternative efficient treatment techniques without hampering the environment. Hence, the present literature survey mainly concentrates on the various wastewater treatment techniques and their advantages. Moreover, the focus of the study is to describe the methods for the reduction of environmental waste and effective utilization of recycled water with zero wastewater management technique. The alternative method for the reduction of textile waste are also covered in the investigation and also suggests the utilization of solid wastes after treatment of wastewater in other sectors like construction for the preparation of low-grade tiles and or bricks by replacing the cement.

The current research work is an identification of sustainability of textile wastewater management (STWM) practices and subsequently to suggest a conceptual framework that influences the STWM practices on performance improvement. By exhaustive literature review, STWM practices are examined and designated highly significant STWM practices for further analysis. The proposed design shows a clear interpretation of sustainable textile wastewater management that depends on economic performance, environmental impact, and operational performance. This framework mainly provides information to society, textile sectors, labors, manufactures as well as users to reduce the wastes by implementing suitable waste management strategies. It was also observed that this study could provide a new direction to the textile manufacturing sectors for determining other related practices as well as performances for future study.

Hence, sustainable waste management innovative technology needs to be applied initially in developing countries to implement new technology, new vision, labor awareness program, and policymakers' initiation.

In textile sectors, much attention was focused in the field of technology, waste utilization, and reduction of effluent during treatment of textile fibers. However, there was no specific study on the sustainability of textile wastewater management principle by using exploratory structural equation modeling (SEM). Therefore, to achieve the above issues, major factors were identified through exhaustive literature, and then a test was conducted for the reliability of the proposed constructs for validation. Moreover, a conceptual framework for sustainable textile wastewater management concept in the textile industry was developed, and further, the proposed model was examined based on the effect of economic performance, environmental impact and operational performance in textile sectors. Finally, the proposed structural model was validated by confirmatory factor analysis (CFA) and structural equation modeling with the help of the SPSS software package.

The textile industry is quickly emerging worldwide and has a beneficial influence on the economy of any country. The waste-water generated with the growth of the textile industry creates important health and environmental issues if not treated properly. Generally, physical, biological, and chemical processes alone or in combinations were used for the treatment of textile waste-water. Besides, the efficiency of any one of the treatment process depends upon the working criterion. In this work, a new hybrid methodology based on the fuzzy analytic hierarchy process (FAHP) and the fuzzy technique for order preference by similarity to ideal solution (FTOPSIS) was proposed to help the workers in textile industries for selecting optimal waste-water treatment process. The factors such as labour input in the textile industry, textile industry productivity, policy implication, waste-water treatment and disposal, energy consumption and carbon dioxide emissions, textile reuse and recycling, dyes and additives and improvement of sustainability-related performance such as economic performance, environmental impact and operational performance respectively were selected as criterion, while, the treatment processes were defined as alternative. To illustrate how this hybrid methodology was used for waste-water treatment problem, a case study involving eleven assessment

criterion and four treatment process used in textile industries in India was conducted. The case study reveals the usefulness and practicability of the proposed methodology. The major objective of this study was the identification of significant factor for sustainable development in textile industries and preferred textile wastewater management practices for environmental protection.

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TABLE OF CONTENTS

List of Figures

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List of Tables

****

Chapter-1

Introduction

1.1 Research background and motivation

Nowadays the production of textile products and consumption have enormously increased in India as well as in other developing countries due to an increase in global population and also improvement of textile living standards. Textile products are mostly used in all most all the manufacturing industries, and the major part is used mostly in fashion industries. This waste from fashion industries needs to reduced either by adopting lower consumption, bettered production procedures, or ultimately via recycling and upcycling methods. With the increased in uses of textile products, the generation of textile solid wastes is increased globally [1]. As per SEPA (2011) report last one decade specifically in Sweden, the textile consumption rate was escalated by 40%, whereas, the home textile and annual clothing consumption was 15kg/capita [2]. Similarly, countries like Finland and Norway the consumption rate was 13.5 and 22kg/capita [3,4]. These textile products produced from different types of textile fibers such as natural, natural cellulosic, synthetic as well as viscose and rayon fibers respectively. However, the consumption rate was drastically decreased in the year 2008 due to the global financial recession by 4.3% and then further increased by about 13% from 2008 onwards [5].

Textile industries are continuously growing with the improvement of textile products along with improvement of global economic condition that brings notice that significant amount of wastes are generated which harms the environment seriously. These wastes are ultimately mixed with river water as well as create environmental issues globally. Hence, it is an excellent challenge to balance the economic development and protection of the environment. Most of the researchers were concerned both economic condition improvement simultaneously improvement of technology improvements to reduce waste textile effluents by recycling the textile wastes [6,7].

1.2. Overview of textile recycling system

Hawley in 2006 developed a theoretical framework based on the qualitative data collected from different textile recycling industries and analyzed that in the United States starting from the recycling of textile wastes to the collection of textile wastes and sorting to foreign exports. However, textile recycling was an established process by understanding various researchers' models that textile recycling as a system [8] and observed that most of the American textile industries digging the textile solid waste in landfills. However, again, Hawley [8] proposed both micros as well as macro continuum framework to understand the behavior and attitudes of individuals that correlated with the effect of the whole system. Again, in the year 1968, Ludwig Von Bertalanffy [9] developed a systems theory in the book in the name of general systems theory that mainly evolved a variety of disciplines from the existing systems. Similarly, another American ecologist (Howard T. Odum) published the general system theory that mainly focused on the design and external relationship functions outcome of the system [10]. However, in case of the textile waste management system, these wastes were diverted from municipal wastes and landfills in order to recover economic values by systematically collecting these wastes sorting them for resale, reuse, and recycling.

Hawley in the year 2000 proposed that the recovery and handling of textile waste was a complicated process because that includes policymakers, recycling management, non-profit organization involvement, and profit business modules, respectively [11]. However, data observed from the U.S. Environmental Protection (2014) Agency, only 15.7% were recovered for reuse and recycling, out of 14.33 million tons annually discarded in the United States [12]. This data indicated that a massive quantity of solid wastes was still unutilized for further recycling instead of landfills and hence, further constructive research was further required for the effective recycling process. In order to influence systems and begin their restructuring, systems thinkers can identify leverage points that can facilitate systemic change [13]. A comprehensive analysis of the overall process of the system is needed to execute the goal of reduction, reuse, and recycling [8].

1.3. Recycling of textile wastes

Council for textile recycling (2014) reported that nearly 45% textile waste reused, 30% converted to different product utilization, 20% were recycled to fiber for other manufacturing products and rest 5% ultimately disposed of as solid waste [14]. China generally produced new virgin yarns from the worn out clothes were shredded and reprocessed by hand for the production of new textiles [8] because these clothes were inherently recyclable materials. Hence, the general public and the manufacturing textile sectors should think about recycling of waste textile effluents. As the recycling process mainly focused on the recycling of waste to the development of new products either is used in the same sector or for any other manufacturing sectors. Hence, most of the recovered textiles waste were not recycled but were reused or repurposed (Secondary Materials and Recycled Textiles) for industries like furniture stuffing, home insulation, automobile soundproofing, building materials, and other products [15].

McDonough and Braungart (2002) proposed textile waste remanufacturing was an excellent thought that was equal to food, but most of the wastes are not specialized to any single type of fibers that are blends of natural as well as synthetic fibers that are difficult to separate [16]. For example, Jimtex Yarns manufactured by 100% cotton fiber that was blended with a small quantity of acrylic or polyester and after spins, the new yarn was used weaving new textile. Whereas, the matrix fiber produces other types of blended recycled fiber items or products in various applications. Domina & Koch, (1997) identified that the textile wastes in the early 90s generally used for landfill disposal purposes and subsequently, the landfill sites availability were gradually decreased although every industry has landfill sites. Hence, the idea of recycling was accepted globally due to the problem in the disposal of the textile wastes either in landfills or draining to river water [17].

1.4. Textile waste resource recovery

To the textile recycling movement the textile waste is one of the biggest obstacle for the recovery of post-consumer textile waste [18], a sentiment that echoed all the organizations such as Council for Textile Recycling, Secondary Materials and Recycled Textiles trade organizations respectively. These organizations are both actively engaging campaigns to increase recovery rates in the United States, seeking to utilize textile waste for new purposes over sending it to landfills for disposal. Hence, to achieve higher recycling rate and donations specifically from educators, charity organizations, consumers and retailers must all encourage consumers to engage in textile recycling efforts [19]. These efforts must also be included in participation of central as wellas state governments to maximize the potential for subsequest success. Therefore, by increasing the recovery of pre as well as post-consumer textile, the apparel waste can create economic opportunity along with reduced the environmental impact. As part of paving the way for the recapture and recycling of textiles, policy-makers must create an environment that allows for the easy disposal and free-flow of all recyclable materials, including textiles solid wastes[20]. Municipal curbside textile recycling collection can decrease the number of textiles sent to the landfill while having positive effects on the environment. Proper collection and handling of textile waste by diverse stakeholders, including municipalities, non-profit, government agencies and for-profit businesses, can contribute to economic as well as ecological benefits and move communities closer to zero-waste goals.

1.5. Contemporary textile waste management

Whenever customers decide to discard their used and old garments they have several options in their hand where they can give their clothes such as either to sell them to retail collectors or professional collectors or they can also donate to some charity organizations and municipalities who transfer these garments to the needy. There are few countries around the globe like Europe, they are buring the discarded textile or landfills them along with the municipal solid waste. Whenever these donated or sold textiles arrive, they are sorted according to their quality and then further sent to reuse or recycling plants for further course of action. East European or African countries receive the significant number of textiles that are of high quality and are in the condition that can be reused [21], whereas others which are not in reusable conditions are sent to the recycling plants. There are only a few textile recycling techniques available around the globe; therefore most of these discarded textiles are turned into rags, wipes, and some of these are even utilized for insulation purpose in several industries. The rest of the leftover collected, used textiles are either incinerated or landfilled with other wastes. In certain circumstances people who do not wear old clothes they store them in their closets and also sometimes informally exchange with their family members and friends [21].In the present scenario, the charity organizations and different industries of European Union can collect only 25 % of the textile waste for reuse or recycle purpose whereas remaining of the leftover textile waste is being sent to incinerators or landfill [22]. At present effective technologies for recycling different types of fibers lack which tends to limit the implementation of recycling techniques. Despite this inadequacy, some efforts have been made to produce recycled fibers by implementing a few small-scale recycling methods [23].

1.6. The Interconnection within business and sustainability

Past few decades, industries and sustainability correlation issue have been shown in different dimensions due to adopting sustainability principles mean investment, changes, business cost, and efforts for innovation, respectively. Whereas, in general, industries were managed their impact in different society ways and also managed the natural ecosystem. However, the sustainability approach implementation in any sectors could give a better strategic opportunity for an increase in growth as well as catch attention for relative profit to a customer who is serious about environmental sustainability. In the traditional business model, the business policy has become simple and easiest way to understand the policy whereas, implementation of sustainable business model has become more complex nowadays. This may be because by adopting sustainable business model has many different factors like economic and financial impact, the greater challenge at a global scale, and enhanced customer awareness respectively. Hence, there are lots of challenges by adopting an integrated economy that may give a sustainable business model as compared with the traditional business model. Hence, with the increase in a broad spectrum of new expressions related to sustainability was dispersive albeit this usage of distinguished terminologies concerning sustainability has turned out to be of great importance to prevent misconceptions as well as confusions[24].

1.6.1. Principles of sustainability

The sustainability approach was formally implemented under the name of sustainable development as it is responsible for addressing the demands of the current generation without compromising on the future generation’s needs along with keeping their own needs as well[25]. Few ideas have been developed by bearing this concept in mind like growth and improvements of life quality, fundamental dynamism of the world contrivance, further steady development in conjugation with the restriction of available resources respectively. The second phase inculcated the long-standing perspective that incorporates the main focus on the future generations which includes all kinds species like living beings, comprising human beings, plants and animals, consistently persecuting intergenerational equity and they all must be kept in harmony. Thereby, space and time are linked together to stipulate the consequences of human activities in regards of both, without fixed boundaries in spatial dimensions as well as with temporal one bearing in mind that current time is crucial for a future time. Sustainability tends to remain ideal towards which one to strive for and against which needs to take proposed actions, expenditures, plans, and final decisions. It is a practice of looking in the broadest way possible towards a community or society or some planet, in the context of both times as well as space. Regarding this, there are two distinctive approaches associated with sustainability. Out of two first one is entitled as "hard sustainability" approach, which presupposes that natural capital can not is replaced by human capital, where the last one in the list is considered as a stock of scarce natural resources that are depleting continuously. On the contrary, the second one is entitled as "soft sustainability" approach, which claims that the replacement amongst the two described capitals is possible, that is mainly concentrated towards upgrading technological abilities [26].

1.6.2. Three pillars of sustainability

Sustainability is mainly dependent upon the following three issues, such as economic development, social advancement, and natural/environmental system protection, and all these identified issues are also connected. However, still, the consolidation and combined effect of these identified issues are in the developing stage in terms of the business world.

Different cultures around the globe have already identified that there is a massive need of harmony amongst all three issues, i.e. social, economy, and environment. It is contradictory to notice that effect on the environmental system has come into limelight only in the last period, as all kinds of human activity are directly or indirectly affecting the eco-system. Talking about an economic activity which is within the environmental context, the transformation of raw materials as well as people labour into some marketable outputs. Nevertheless, the underlying information related to worldwide industrialization, technology advancements, and information community alters and modifies the approaches, actions, and decisions that need to be taken while dealing with sustainability.

Improvement of human well-being, social balance, and significant reduction of risks associated with the environment and eco-system deficits leads to the birth of the term “green economy”. This expression cannot be taken as the unique proposition as among past few years this term has presumed lots of meanings, as in general interpretation of this term “green economy” comprises of green policies and green business schemes. However, the term “green economy” encompasses and considers all the aspects that integrate the relationship between economy and environment.

1.6.3.Progression of sustainability in management

Environmental tensions commenced during the early nineteenth century, when people at international level started trading, openness for financial and capitals were intensified particularly after the Second World War after which western countries experienced higher economic growth rates. As a result of this, the sustainability issues first and foremost confronted were associated with natural eco-systems’ related problems stemming from worldwide businesses. As a matter of the fact that humans, who are solely responsible for causing the devastation, misuse, and demolition of available natural resources, are now making efforts in attaining awareness related to the sufferings caused within the ecosystem due to his activities. Henceforth, it is imperative to attain a knowledge of the leading factors that are responsible for causing environmental pollution, mainly in the textile and apparel sectors. To bring sustainability manufacturing process into textile industries, some strategic plannings may also be incorporated like formulations of techniques such as principal component analysis (PCA) and FTOPSIS techniques. These techniques tend to make an important place for themselves as they are quite helpful in modern decision making while researching any field.

The principal component analysis (PCA) is a technique that is practiced in diverse fields for researching as it is simple as well as the non-parametric procedure that helps in easy retrieval of information from confusing sets of available data. All hidden facts and simplified structures that underlie in a complex set of data are uncovered and brought to lower dimensions by PCA technique with minimal efforts and are one of the most widely used methodologies for studying multi-variables in a single study. This technique employs mathematical procedures in transforming a set of a large number of correlated variables into a less number of uncorrelated variables that are generally called as principal components. Even though PCA is employed for minimizing the number of variables in a provided data set, yet it is capable of retaining the majority of the original variability in the available data. PCA method can be exercised for calculating and ranking the competitive level of different textile industries across the globe or in a specific regional area for studying the domains like textile quality control, textile wastewater, dyestuff comparison, seam puckering, etc. Whereas, FTOPSIS(Fuzzy technique for order preference by the similarity of an ideal solution) approach is generally used for ranking the available alternatives. FTOPSIS is, in general, an extended version of TOPSIS while conducting the study under fuzzy circumstances, which is in particular based upon the fuzzy ideal points and fuzzy negative ideal points. This methodology mainly focusses at finding the point that is much closer/near to the fuzzy ideal points and most far away to the fuzzy negative ideal points.

Rewarding thanks to all the scientists and various researches whom all provided evidence concerning climate change and global warming during the late 1960s. All the adverse effects of economic activities on the environment and eco-system were acknowledged, and after that, the principle of “sustainable management” has emerged slowly on its own. Remarkable motives of sustainability development were structured and organized by Hart and Milstein (2003) revealing the main agenda of sustainability development [27]. Growing industrialization will lead to an increased rate of pollution, more consumption of resources, and ultimately creating waste. Collaboration amongst non-governmental organizations and environmentalists with the assistance of the IT sector has empowered principles diffusion. Disruptive and in some instances uncertain innovations of technology, ever-increasing population, poverty as well as inequality has to lead the need for sustainable development practice to be embedded into almost all the sectors to forecast the activities of human beings around the world.

The next chapter deals with the literature review on the various topics covered in the present research work. From the past studies, the research gaps are identified, and the objective of the present reproach work is reported.

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Chapter-2

Literature Review

2.0. Introduction

This review chapter seeks to describe, clarify, evaluate, and /or integrate the content of primary and previous published reports on various treatment techniques for recovery of wastewater as collected from textile industries, utilization of wastes effluents and hybrid multi-criteria decision making techniques for improvement of textile sectors performance respectively. The study also describes the methods for effective utilization of waste water by low cost techniques using various industrial wastes as an absorbent for effective treatment of textile wastewater. An intensive research is conducted to develop an understanding of low cost treatment techniques for successful use of various textile wastes. Therefore, the present study reviews the following issues and finally proposes the best alternative,

- Study on different purification techniques for treatment of textile wastewater
- Study on effective utilization of low-cost absorbent for treatment of textile industrial effluents
- Study on effective utilization of textile sludge for preparation of concrete structure in the replacement of cement
- Study on direct reusing of textile wastewater without further secondary treatment
- Study on Cost-Benefit Analysis of textile wastewater used in textile industries
- Study on comparative analysis of hybrid multi-criteria-decision-making techniques for sustainability of textile wastewater management
- Future scope of research

2.1. Study on different purification techniques for treatment of textile wastewater

The real problem behind the industrial textile waste water was extremely carcinogenic in nature, allergic and simultaneously toxic characters simultaneously other environmental issues. Textile dyes for the textile industries give high impact due to colorful along with different dyes have different significance in a society which is a significant concern in the present world. However, the same textile dyes after cleaning or washing of textile fibers after color produce huge environmental pollution. The wastewater contains not only colored but also other metallic particles, high fluctuating $_{P}H$, suspended solids with high COD, etc [28,29]. Therefore, in the present day, the textile wastewater from textile and dyeing industries major concerned was the treatment of textile wastewater and reused for textile processing because of the high quantity of biological-oxygen-demand (BOD), P^{H}, color, chemical-oxygen-demand (COD), and the existence of solid metal particulates [30-34]. However, other researchers also reported that about the toxicity of wastewater effluents by way of biological systems and attempted to reduce the toxicity effect [35, 36].

Jeihanipour et al. [37] proposed an original process for production of biogas from cellulose in blended waste textiles fibers and then the solvent, N-methyl morpholine-N-oxide used for pretreatment of cellulose. They reported that waste textile cellulosic part separated from the noncellulosic fibers by the proposed N-methyl morpholine-N-oxide method. Foo and Hameed [38] discussed the textile waste treatment new technology along with challenges facing at the time of dyes treatment and pointed out its future consequence. They reported that dye processing industries or sectors specifically in a textile generation might be failed in future without any environmental pollution control. They also suggested that adoption of titanium dioxide accommodation oxidation was capable of fundamental approach for wastewater treatment and detoxification of the processes that recover the catalyst from the slurry stream [39,40].

Barredo-Damas et al. [41] suggested ultrafiltration process may be an alternative for pre-treatment of textile wastewater through membrane separation processes such as nanofiltration and reverse-osmosis process respectively and finally, 99% turbidity with 82-98% color have removed along with chemical oxygen demand (COD) also reduced between 62 to 79% successfully. However, in a conventional process for wastewater treatment mainly physicochemical and biological treatments by activated sludge method were frequently used but after treatment the same wastewater could not be reused for textile processing sectors [42-48] (Table 2.1).

Ashwin et al. [50] studied textile liquid wastewater treatment through Sequential-Batch-Reactor (SBR) technique and performed the pre as well as post-treatment using sonochemical reactor. They observed that in this method the treatment process the effluent was vigilantly diluted to get desired chemical-oxygen-demand concentration, but the cost can be successfully managed by using SRB technique with pre as well as post treatments. Similarly, few researchers were used bioaugmented membrane bioreactor (MBR) [51], anaerobic batch reactor [52], bioreactor typology technique [53-55]. However, acidogenic reactor, methanogenic reactor [56], recycle reactor [57], photoelectrocatalytic reactor [58], toxic reactive Blue Bezaktiv S-GLD 150 dye [59] and fixed bed reactor [60] used for removal of total organic carbon.

Table 2.1. Conventional techniques adopted to treat the wastewater [30-48]

Sl. No.	Types of techniques	Treatment
1.	Physical	Sedimentation, flotation and skimming, filtration, screening, aeration, degasification and equalization
2.	Chemical	Chlorination, ozonation [49], coagulation, neutralization, adsorption and ion exchange
3.	Biological	
	a. Aerobic	Activated sludge treatment methods, lagoons, Trickling filtration, ponds, oxidation, aerobic digestion
	b. Anaerobic	Anaerobic digestion, septic tanks, Lagoons

Khlifi et al. [61] reported that de-colourization and de-toxification of textile waste water by laccase from Trametes trogii and investigated in the absence of laccase mediators. They observed that laccase was not able to decolourize the effluent, where the enzyme concentration was slightly higher. Again, Khouni et al. [62] studied three different processes to observe the decolourization efficiency of textile effluent from the laboratory prepared waste water consisting of two different reactive dyes and found that in coagulation/flocculation method 93% of colour removed whereas, in commercial laccase catalysis reduces the colour by 99% respectively.

Similarly, most of the researchers were repeatedly cited their research work in different platform about the dye removal process such as membrane separation process, reverse osmosis, coagulation technique, chemical oxidation demand, electrochemical process, aerobic and anaerobic microbial degradation process respectively were successfully implemented in textile industries. However, all the techniques were not cost-effective, and these methods have a lot of restrictions for successful removal of colour from waste water efficiently [63, 64]. Such as Merzouk et al. [65] investigated both the mixed wastewater and textile wastewater on the treatment of pure red dye solution by electrocoagulation technique [66] and observed that textile waste water was not fully treated whereas, pure red dye solution was suitable with the higher level of color and organic pollution abatements. Finally, proposed that more accurate evaluation technique was needed to improve the treatment efficiency of the mixed wastewater. Similarly, other industries like food industries [67,68], tanneries [69,70], heavy metals [71-74], mechanical workshop [75,76], polymerization manufacture, and textile industries [77-80] were followed electrocoagulation treatment technique specifically highly polluted industrial wastewater locations. Hence, based on the above-studied techniques for treatment of textile wastewater, very few treatment techniques were used efficiently in textile Industries. Therefore, development of demands for making of textile dyes, an inexpensive method is required with minimum chemical and energy consumptions. Now-a-days electro-coagulation technique was very frequently used by the textile Industries [81]. As electro-coagulation technique was simplest and an efficient method applied in most of the wastewater treatment plants. The waste water generally contains oil wastes [82, 83], textile waste water [84], dye [85-88], foodstuff waste [89], heavy metals [90-93], fluoride and polyvinyl alcohol [94], for removal of Bomaplex Red CR-L [95] by electrocoagulation process. They successfully removed colour by coagulation and flocculation technologies [96], respectively.

Similarly, biological treatment process the treated textile effluent by reverse osmosis (RO) [97,98] and nanofiltration membranes[99-103] for reuse of water and also observed that reverse osmosis and nanofiltration membranes could successfully remove COD, BOD, and color of the biologically treated effluents. Similarly, removal of metal ion mixture (i.e., textile dye and metal ion) and dye decolorization can also possible by the electrochemical treatment process. They also explained that by this technique rapid decolorization could also be achieved by complete reduction of both acid dyes and reactive dyes [104]. At the end, proposed that the electrochemical treatment process was one of the efficient techniques to remove binary mixtures and textile dye decolorization respectively. However, limitation of the technique was unable to mineralize the organic pollutants and other by-products completely [105].

Again, now-a-days most of the researchers mainly focused on various microorganisms [106-108] which degrade azo dyes [109-113] two different conditions such as anaerobic and aerobic conditions respectively [114-119]. Hence, based on the impact of azo dye one of the efficient treatment process specifically for Textile wastewater treatment Cui et al. [120] reported that azo dye decolorization rate was higher with the use of consortia as compared with individual strains. Bacterial consortia can be decolorized by methyl red under aerobic and anaerobic conditions respectively [121-124]. Similarly, Eren [125] reviewed more than 100 research papers on ultrasonic treatment process with biochemical, electrochemical, photolysis, photocatalysis respectively[126-128]. Whereas, fenton [129, 130], electro fenton [131] and azonation processes respectively used specifically for textile dyes and dye bath due to cavitation phenomenon occurs which increases the efficiency of advanced oxidation processes [132-136].

Wang and Peng [137] discussed the scientific utilization of natural zeolites used as adsorbents for purification of wastewater and water obtained from Textile dye industries, municipality waste or treatment plants wastewater respectively. They also reported that the modified zeolite shown better adsorption capacity specifically for organic and anions. Similarly, Hedstro¨m and Amofah [138] studied natural zeolite as clinoptilolite having a maximum adsorption capacity of ammonium about 20mg/L with a maximum grain size of 4-8mm. They also estimated that for smaller grain size the adsorption capacity was more as compared with other natural zeolites like natural Bulgarian zeolite treatment [139-146], zeolite-clinoptilolite [147], bentonite [148,149], sepiolite [150], zeolite [151], was used to remove color [152,153] from aqueous solutions.

Martellini et al. [154] collected two different plants such as textile wastewater and municipal wastewater to obtain the concentrations, compositional profiles and contribution to ambient levels and observed that polybrominated-diphenyl-ethers concentration was higher in textile wastewater. They also proposed that plant distance from the source and wind direction on atmosphere also cover the environment. Loncar et al. [155] discussed cheap enzyme sourced from potato polyphenol oxidase for decolorization of seven different textile dyes and three different dye effluents and reported the optimized condition was achieved for removal of dyes of about 93-99.9%. Finally, recommended that potato polyphenol oxidase was capable of extracting reactive dyes and effluents without any intermediate and than decolorization [156] was obtained via insoluble polymers by filtration.

Derden and Huybrechts [157] determined a new technique for reduction of Deca-BDE emissions from the textile industry, Decabromodiphenyl ether (BDE) is increasingly used in textile industry now-a-days for production of cotton and synthetic fibers for clothing and carpets. As Brominated Flame Retardants was used to protect the fibers from burning without depending on the texture, colour as well as the appearance of the prepared fabrics [158]. Hence, during finishing process more amount of Deca-BDE was mixing with the waste textile water and was harmful to the environment as well as soil. Therefore, the additional technique was identified as Emission levels associated with the best available techniques (BAT-AEL) as an other parameter, which confirmed that the emission data with the determined BAT-AEL range was lesser than 20mg/l. Table 2.2 indicates a summary of various textile industries treatment techniques and other alternative techniques for textile wastewater.

Table 2. 2. Summary of various conventional and advanced treatment techniques used in textile industries

Sr No.	Name of the journal/Author	Year of Publication	List of Experiment Performed	Methodology	Key issues addressed	Location Specific	Remarks	Ref. No.
1	Bioresource Technolog/ **Ibrahim M. Banat et al.**	1996	Azo dyes used as adsobet. Acticated sludge used as adsorbent	biological decolorization	1. Biological processes could be adopted as a pre-treatment decolorization step, combined with the conventional treatment system.	----	1. Concerted efforts are still required to establish biological decolorization systems.	28.
2	World Journal of Microbiology & Biotechnology/ **Dapinder K. Bakshi et al.**	1999	Adsoption & Enzymetic degradation	Biodecolorization	1. Increase of 6.7-fold in lignin peroxidase (LIP) level, 4-fold in biomass and 45.5% enhanced decolorization of effuent was achieved.	Chandigarh India	1. To obtain maximum decolorization of synthetic dye effluent through adsorption as well as enzymatic degradation.	29.
3	Biodegradation/ **Resmi C. Senan & T. Emilia Abraham**	2004	Isolation and screening, Analytical determinations	Bioremediation	1. Dyes removal decrease. 2. Aerobic bacterial consortium was developed for the decolorization of textile azo dyes.	Trivandrum, India	1. Dyes are converted to low molecular weight compounds and amines were absent	30.
4	Desalination/ **Suman Koner et al.**	2011	Batch and continuous operation	Adsorption process	1. Adsorption, Cationic surfactant 2. Silica gel waste, 3. Adsolubilization	Hooghly, India	1. use of silica gel waste (SGW) as an adsorbent	31.
5	New Biotechnology/ **Antonella Anastasi et al.**	2011	Decolourisation experiments	Fungal treatment	1. decolourisation , 2. detoxification, 3. fungal treatment, 4. dyeing process,	Italy	1. Bjerkandera adusta was tested in different culture conditions to assess its real potential for bioremediation of textile wastewaters	32.
6	Trends in Analytical Chemistry/ Iva Rezic	2011	Separation	Liquid/solid extraction	1. Engineered nanoparticle 2. Separation	Croatia	1. Important techniques for monitoring ENPs on textile materials and in textile-wastewater samples.	33.
7	Journal of Colloid and Interface Science/ **Eliana W. de Menezes et al.**	2012	Kinetic and equilibrium study	Adsorption studies	1. Sol–gel, Grafting, Organofunctionalized silica, 2. Effluent treatment, Nonlinear fitting, Dye removal from aqueous solution	Brazil	1. Development of an ionic silica based hybrid material containing the cationic pyridinium group, remove the dye	34.

8	Bioresource Technology/ **J.P. Jadhav et al.**	2010	Dyes and chemicals analysis, Isolation, screening and microorganisms, Decolorization assay	Biotreatment	1. Reactive Orange 16 adsorbate used. 2. Significantly higher reduction in color, COD, BOD and metal ions in much less time, by utilizing the components of the wastewater for the growth.	Kolhapur	1. Becolorization of the textile effluent revealed the nontoxic nature of the biotreated sample	35.
9	Bioresource Technology/ enek Novotny et al	2011	Fungal trickling filter treatment	Biological method	1. Textile wastewater treatment, Fungal trickling filter, Mixed bacterial community, Irpex lacteus, Two-step degradation process.	Austria	1. Efficiency of a sequential biodegradation process using fungal and mixed bacterial cultures for treatment of textile wastewater.	36.
10	Waste Management/ **Azam Jeihanipour et al.**	2010	Separation procedure, and fermentation to ethanol, Digestion to biogas,	enzymatic hydrolysis process and Analytical methods	1. Initial rate of enzymatic hydrolysis by 8–14-folds and the initial rate of biogas production by more than 15-folds.	Sweden	1. Cellulose solvent, N-methylmorpholine-N-oxide (NMMO) was used in this process for separation and pretreatment of the cellulose.	37.
11	Advances in Colloid and Interface Science/ **K.Y. Foo, B.H. Hameed**	2010	Photoexcitation, Diffusion, Recombination, Hole trapping, Oxidation	molecular adsorption deposition method	1. Crude titanium dioxide is typically extracted from minerals ilmenite, leucoxenes ores	Malaysia	1. Textile waste dyes treatment via titanium dioxide/activated carbon composites treatment processes.	38.
12	Ind. Eng. Chem. Res/ **David M. Follansbee et al.**	2008	Pressure Drop and Pumping Requirements	novel continuous photocatalytic reactor	1. introduce a novel continuous photocatalytic reactor configuration that addresses the difficulties of particle separation, process scalability,	*Albany New York*	1. systematic methodology that identifies globally optimal key design parameter values and associated optimal operating process conditions for a continuous advanced oxidation process	39.
13	Trans. Nonferrous Met. SOC CHina/ **FU Ping-feng et al.**	2006	SEM-EDX, XRD, XPS and FTIR,	molecular adsorption-deposition	1. interposition fixing structure; stability	Beijing, China	1. TiOz film anchored on activated carbon fibers (Ti02/ACFs), shows high stability in the cyclic photodegradation runs	40.
14	Desalination/**S. Barredo-Damas et al.**	2010	Analytical methods, ultrafiltration,	Ultrafiltration process	1. Ceramic UF membranes proved to be a feasible pre-treatment alternative.	Spain	1. Ultrafiltration process was applied successfully for textile wastewater treatment in order to	41.

			Experimental procedure,		2. Turbidity and color removals seemed to be more influenced.		adapt this effluent for a later NF/RO stage.	
15	Journal of Hazardous Materials/ **G. Capar et al.**	2008	Flux decline analysis, Membrane chemical cleaning,	NFT-50 membranes, Nanofiltration, Analytical techniques	1. Beck-dyeing used as adsorbates. 2. low COD rejection at acidic pH can be speculated as the passage of acetate ions	Turkey	1. separate water reuse schemes offered for print-dyeing and beck-dyeing wastewaters	**42.**
16	Desalination/ **Loredana De Florio et al.**	2005	Pilot scale treatment	Nanofiltration	1. Textile effluents; Water reuse; Nanofiltration	Italy	1. Nanofiltration of the investigated effluents proved to be a cost-efficient treatment work. .	**43.**
17	Environmental Science & Technology/**bartv anderbruggen et al.**	2005	Microfiltration, ultrafiltration, nanofiltration, and reverse osmosis	pressure-driven membrane processes	1. To treat or discharge the concentrate	Belgium	1. Pressure-driven membrane processes results in the generation of a large concentrated waste stream.	**44.**
18	EPA Manual/	1996	General Waste Categorization	Pollution Prevention Approaches	1. Pollution prevention opportunities are identified for specific textile processes	US	1. successful implementation of pollution prevention in textile processing	**45.**
19	Desalination/**HarshaP. Srivastava et al**	2011	Treatment of dye effluent	Membrane separation method	1. Modified PVDF membranes showed moderate color removal, COD reduction .	Tirupur, Tamilnadu	1. The modified PVDF membranes were capable of successfully removal of around 97% of CR dye and over 70% of RB5 dye from the feed solutions	**46.**
20	Desalination/ **A. Aouni et al**	2012	Ultrafiltration Nanofiltration	Membrane separation method	1. Ultrafiltration, Nanofiltration, 2. Reactive dyes, Rinsing wastewater	Spain	1. Ultrafiltration and nanofiltration processes were used to treat synthetic reactive dyes aqueous solutions.	**47.**
21	Chemical Engineering Journal/**S. Barredo-Damas et al**	2012	Ultrafiltration	Membrane separation	1. Ceramic membranes, Textile wastewater, Ultrafiltration 2. Water reclamation	Spain	1. performance of tubular ceramic ultrafiltration membranes treating 2. integrated raw effluents from a textile mill.	**48.**
22	Dyes and Pigments/ **Kadir**	2012	bench-scale reactor	Ozonation	1. Ozonation, Methylene Blue 2. Basic dye, Kinetics,	Turkey	1. Decolorization of the dye was achieved by ozonation.	**49.**

	Turhan et al							
23	Desalination/**Ravichandran Ashwin et al.**	2011	Pre and post-treatments by sonolysis, Kinetic study	SBR treatment & Sonolysis	1. SBR technique with an advanced oxidation process like sonolysis, it is possible to achieve reasonable time management and cost effectiveness	Chennai	1. Optimization of time allocation for SBR and sonolysis at various stages through a simulation for normal and shock loads of textile effluents	**50.**
24	Water research/**Faisal Ibney Hai et al**	2011	Microorganism and synthetic wastewater, Design and feeding mode of the bioreactor,	Biological treatment	1. Use of the GAC-zone for dye removal.	Japan	1. Stable decoloration along with significant organics (TOC, TN) removal over a prolonged period under extremely high dyeloadings was observed.	**51.**
25	Bioresource Technology/ G. Gnanapragasam et al	2011	Batch studies anaerobic digestion technique	anaerobic digestion technique	1. Batch reactor, Kinetics, Anaerobic digestion, Starch, Textile dye	Annamalainagar, India	1. An anaerobic digestion technique was applied to textile dye wastewater aiming at the colour and COD removal.	**52.**
26	Bioresource Technology/ **B. Balamurugan et al.**	2011	Anaerobic biodegradation	microbial method	1. Halotolerant bacteria, Reactive textile dye, Anaerobic degradation	Coimbatore, India	1. Reduce the COD and color of the effluent containing reactive textile dye by microbial method.	**53.**
27	International Biodeterioration& Biodegradation/ SimonePapadia et al	2011	Microbial characterization	Biological method	1. Wastewater treatment, Reactor configuration, Fluid dynamics, Microbial characterization	Italy	1. Comparison of different pilot scale bioreactors for the treatment of a real wastewater from the textile industry.	**54.**
28	Separation and Purification Technology/ **Chia-Chi Su et al.**	2011	Fluidized-bed Fenton	Oxidation	1. Textile wastewater, Hydrogen peroxide, Decolorization, Fluidized-bed Fenton	Thailand	1. Treatment of textile industrial wastewater by the fluidized-bed Fenton process.	**55.**
29	Chemical Engineering Journal/**M. Senthilkumar et al.**	2011	Upflow Anaerobic Sludge Blanket reactor	Biological method	1. Textile dyeing wastewater, 2. Colour removal, Sago, 3. Two-phase UASB	Tamilnadu , India	1. Decolourization and removal of degradable organics with tapioca sago wastewater	**56.**
30	Desalination/ **C. Ahmed Basha et al.**	2012	Batch reactor	Oxidation	1. Batch recirculation reactor, Recycle reactor, Procion blue, Specific energy consumption	Tamil nadu	1. Dye-bath and wash water effluents of a textile industry were subjected to	**57.**

							electrochemical oxidation in batch reactor.	
31	Journal of Photochemistry and Photobiology/ **R.T. Sapkal et al .**	2012	Photoelectrocatalytic decolorization and degradation	Photoelectrocatalysis	1. Photoelectrocatalysis, Zinc oxide, Textile effluent, FTIR, Phytotoxicity	Kolapur, India	1. Photoelectrocatalytic decolorization and degradation of textile effluent using ZnO thin films.	**58.**
32	Separation and Purification Technology/**Imen Khouni et al.**	2012	Sequencing batch reactor	Decolourisation	1. Textile effluent, Sequencing batch reactor, Biodegradation, Reactive dye	Tunisia	1. Investigate the biological decolourisation of a widely used textile reactive dye.	**59.**
33	Chemical Engineering Journal/ **Mohamad Anas Nahil, Paul T. Williams**	2012	Activation reactor	Adsorption	1. Pyrolysis, Textile waste Activated carbon, Surface chemistry, XPS	UK	1. Acrylic textile waste was pyrolysed in a fixed bed reactor in a nitrogen atmosphere at three different temperatures.	**60.**
34	Journal of Hazardous Materials/ **Rim Khlifi et al.**	2010	media and culture conditions	Decolourization tests	1. Laccase, Decolourization, detoxify dye effluent	Tunisia	1. Ability of crude laccase from the white-rot fungus T. trogii to decolourize and detoxify dye effluent from the textile industry	**61.**
35	Desalination / **Imen Khouni et al.**	2011	Coagulation, flocculation,	Advance treatment	1. Coagulation, flocculation, Laccase catalysis, Nanofiltration	France	1. Decolourization efficiency of textile effluent in different processes achieved	**62.**
36	Bioresource Technology/ **M.T. Sulak et al.**	2007	batch technique	Adsorption kinetics	1. Wheat bran; Astrazon yellow; Adsorption kinetics; Diffusion; Thermodynamic parameters	turkey	1. Removal of Astrazon Yellow 7GL from aqueous solutions by adsorption onto wheat bran	**63.**
37	Chemical Engineering Journal/ **Sevilay Cengiz et al.**	2012	Activation reactor	adsorption	1. Posidonia oceanica , Dye adsorption, Wastewater treatment, Astrazon Red	Turkey	1. Usage of a natural environmental waste, P. oceanica dead leaves, for the removal of dyes from industrial effluents.	**64.**
38	Desalination/ **B. Merzouk et al**	2011	adsorption equilibrium	Electrocoagulation	1. Electrocoagulation, Aluminum, Red dye, Textile wastewater, Mixed waste, Sludge settling velocity	France	1. Efficiency of electrocoagulation for the abatement of COD, TOC, absorbance and turbidity from	**65.**

							a real textile wastewater.	
39	Rev Chem Eng/ **Ahmed Samir Naje**	2016	efficiency; electrocoagulation; operating parameters; pollutant removal	Coagulation concept	1. EC treatment of textile wastewater and highlighted the main drawbacks of this technique	Kuala Lumpur, Malaysia	1. EC process with rotating electrodes, which could reduce the passivation film, enhance homogeneity of electrolyte, and increase the rate of flocs formation	**66.**
40	Separation and Purification Technology/ **Xueming Chen et al.**	2000	COD, BOD	Purification Technology	1. Charge loading; Chemical oxygen demand; Current density; Oil and grease; Removal efficiency	China	1. Separation of pollutants from restaurant wastewater by electrocoagulation	**67.**
41	Int. J. Electrochem. Sci.,/ **Ahmed Samir Naje et al.**	2015	monopolar and bipolar connection aluminum electrode; iron electrode	Electrocoagulation	1. The overall efficiency of EC process was compared to the conventional chemical coagulation process	Kuala Lumpur, Malaysia.	1. The performance of EC was higher than the traditional chemical coagulation based on the difference between the removal efficiency of COD and the Al dosage within the pH range	**68.**
42	Journal of Hazardous Materials/ **A.K. Golder et al.**	2007	Batch experiments	Electrocoagulation	1. Electrocoagulation; Bipolar; Monopolar; Electrode configuration; Current efficiency		1. Removal of Cr3+ by EC from aqueous solution with both monopolar and bipolar electrode configurations is a feasible process	**69.**
43	Separation and Purification Technology/ **Ilona Heidmann and Wolfgang Calmano**	2008	Batch experiments	Electrocoagulation	1. Electrocoagulation, Chromium Iron electrodes; Wastewater	Germany	1. Performance of an electrocoagulation system with iron electrodes for Cr removal from model wastewaters.	**70.**
44	Desalination/ **Merzouk Belkacem et al.**	2008	Batch experiments	Electroflotation	1. Electroflotation; Aluminum electrodes; Turbidity; Textile wastewater; Heavy metals	Algeria	1. Treatment of textile wastewater and removal of heavy metals using the electroflotation technique.	**71.**
45	Journal of Hazardous	2009	Batch experiments	Electroflotation	1. Electrocoagulation-electroflotation, Heavy metals	Algeria	1. Removal turbidity and separation of heavy metals	**72.**

	Materials/ **B. Merzouk et al.**						from textile wastewater using electrocoagulation–electroflotation technique.	
46	Journal of Hazardous Materials/ **Nathalie Meunier et al.**	2006	electrochemical techniques	Electroflotation	1. Metal; Soil; Leaching; Electrocoagulation; Decontamination; Effluent; Removal; Solubilization	France	1. Comparison between electrocoagulation and chemical precipitation based on heavy metals removal from acidic soil leachate (ASL) at the laboratory pilot scale.	**73.**
47	Journal of Hazardous Materials/ **Ilona Heidmann and Wolfgang Calmano**	2008	Batch experiments	Electrocoagulation	1. Electrocoagulation; Heavy metals; Aluminium electrodes; Industrial wastewater	Germany	1. Performance of an electrocoagulation system with aluminium electrodes for removing heavy metal ions from aqueous solution.	**74.**
48	Journal of Hazardous Materials/ **Pablo Canizares et al.**	2008	Electrochemical coagulation experiments	Electrochemical	1. Break-up; Aluminium electrodes; Oil-in-water emulsion; Dosing; Electrochemical	Spain	1. Efficiencies of the chemical and the electrochemical break-up of oil-in-water (O/W) emulsions with hydrolyzing aluminium salts are compared.	**75.**
49	Institution of Chemical Engineers/ **M. KHEMIS et al.**	2005	Batch experiments	electrocoagulation	1. Aluminium, electrocoagulation oil suspensions 2. hydrogen evolution	France	1. investigations of an electrocoagulation process for the treatment of concentrated oil dispersions, used for machining and drilling operations.	**76.**
50	Journal of Hazardous Materials/ **Mehmet Kobya et al.**	2003	Batch experiments	Electrocoagulation	1. Electrocoagulation; Iron; Aluminum; Electrode; Textile wastewater	Turky	1. Treatment of textile wastewaters by electrocoagulation using iron and of aluminum electrode materials.	**77.**
51	Chemical Engineering and Processing/ **A. Alinsafi et al.**	2005	Batch experiments	Electrocoagulation	1. Electro-coagulation; Reactive dye; Colour removal; Experimental design; Biodegradability	Morocco	1. Electro-coagulation of a blue reactive dye solution has been optimised by experimental design in terms of colour removal and COD.	**78.**
52	Chemical	2009	Batch experiments	Electrocoagulation	1. Continuous electrocoagulation,	France	1. A continuous	**79.**

	Engineering Journal/ **B. Merzouk et al.**				Red dye, Decolorization		electrocoagulation process was investigated for decolorization and chemical oxygen demand (COD) abatement of a synthetic textile wastewater.	
53	Journal of Hazardous Materials/ **Inoussa Zongo et al.**	2009	Chemicals and analytical techniques	Electrocoagulation	1. Wastewater treatment, 2. Textile industry, 3. Electrocoagulation, 4. COD, Turbidity	France	1. Aluminium and iron are suitable electrode materials for the treatment of the investigated textile wastewaters by electrocoagulation.	**80.**
54	Journal of Hazardous Materials/ **N. Daneshvar et al.**	2006	Decolorization	Electrocoagulation	1. Electrocoagulation; Basic dye; 2. Decolorization; reduction; 3. Dyeing wastewater	Iran	1. electrocoagulation has been used for the removal of color from solutions containing C. I. Basic Red 46 (BR46) and C. I. Basic Blue 3 (BB3)	**81.**
55	Journal of Hazardous Materials/ **K. Bensadok et al.**	2008	Electrocoagulation	membrane process	1. Electrocoagulation; 2. Cutting oil emulsions; 3. Aluminium plate electrodes; 4. Very high COD	France	1. electrocoagulation (EC) was experimentally investigated as a pre-treatment step prior to a membrane process	**82.**
56	Journal of Hazardous Materials/ **Pablo Ca˜nizares et al.**	2008	Electrochemical Reactor	electrochemical method	1. Break-up; Aluminium 2. electrodes; Oil-in-water 3. emulsion; Dosing; 4. Electrochemical	Spain	1. Efficiencies of the chemical and the electrochemical break-up of oil-in-water (O/W) emulsions with hydrolyzing aluminium salts are compared.	**83.**
57	Desalination/ **B. Merzouk et al.**	2011	batch experimental	Electrocoagulation	1. Electrocoagulation, Aluminum 2. Red dye, Textile wastewater 3. Mixed waste, Sludge settling velocity	France	1. efficiency of electrocoagulation for the abatement of COD, TOC, absorbance and turbidity from a real textile wastewater	**84.**
58	Journal of Environmental Management/ **J. Sánchez-Martín et al**	2010	Buffered solution, Coagulant solution and wastewater samples, Analytical procedures,	Coagulation-flocculation	1. Tanfloc is a highly effective treatment agent. 2. Pilot plant studies	Spain	1. Tannin-based coagulant-flocculant (Tanfloc) was tested for water treatment at a pilot plant level	**85.**
59	Journal of Hazardous	2008	Decolorization	Electrocoagulation	1. Electrocoagulation; Dye; 2. Decolourization; Coagulant;	Morocco	1. Removal of a reactive textile dye (CI Reactive Red 141)	**86.**

	Materials/ **Fatiha Zidane et al.**				3. Aluminium hydroxide; 4. Reactive Red 141;		from solution using both a direct electrocoagulation process.	
60	Desalination/ **Ata Maljaei et al.**	2009	Decolorization	Indirect electrochemical oxidation	1. Textile wastewater, 2. Indirect electrochemical oxidation 3. Aromatic ring degradation 4. C. I. Reactive Yellow 3	Iran	1. decolorization and aromatic ring degradation of colored textile wastewater.	**87.**
61	Desalination/ **P.V. Nidheesh and R. Gandhimathi**	2012	E-Fenton reactors	Kinetics of E-Fenton process	1. Electro Fenton 2. Wastewater treatment 3. Degradation 4. Organic pollutant	Tamil nadu	1. application of E-Fenton on organic pollutant removal from wastewater.	**88.**
62	Ind. Eng. Chem/ **Carlos Barrera-Dıaz et al.**	2006	Electrochemical Reactor	electrochemical method	1. Electrochemical Reactor, organic pollutants, wastewater	Mexico	1. electrochemical method used in this study reduces the concentration of organic pollutants in industrial wastewater.	**89.**
63	Journal of Hazardous Materials/ **Jewel A.G. Gomes et al.**	2007	electrocoagulation reactor	Electrocoagulation	1. Electrocoagulation; Combined Al–Fe electrode system; Wastewater; Arsenic removal; Ionic substitution	USA	1. Aluminum and iron, provides an alternative method for removal of arsenic from water by electrocoagulation.	**90.**
64	Journal of Hazardous Materials/ **Elham Keshmirizadeh et al.**	2011	electrocoagulation reactor	Electrocoagulation	1. Chromium, Electrocoagulation, 2. Alternating pulse current, Optimized operational, parameters, Conductivity	Iran	1. electrocoagulation (EC) process with aluminum/iron electrodes for removal of chromium on laboratory scale.	**91.**
65	Desalination/ **Ashraf Shafaei et al.**	2011	electrocoagulation reactor	Electrocoagulation process	1. Heavy metal, Cobalt ion 2. Wastewater, Electrocoagulation process	Iran	1. Electrocoagulation (EC) process is an effective method for the removal of heavy metal ions wastewater effluents	**92.**
66	Applied Surface Science/ **Maria Visa**	2012	batch experiments	Adsorption	1. Bentonite, Fly ash, Pollutants, 2. Adsorption, Wastewater treatment	Romania	1. fly ash represents a low cost adsorbent for advanced wastewater treatment.	**93.**
67	Chem Eng Trans/ **Nadjib Drouiche et al.**	2011	calcium precipitation experiments	Electrocoagulation	1. calcium precipitation experiments, Optimization, photovoltaic wastewater	Algeria	1. electrocoagulation system using aluminium electrodes was studied for the removal of fluoride from pre treated	**94.**

							photovoltaic wastewater with lime	
68	Desalination/**Alper Erdem Yilmaz et al.**	2011	Batch adsorption experiments	Adsorption	1. Dye removal, Wastewater, Waste utilization, Adsorption, Isotherms, Kinetics	Turky	1. Electrocoagulated metal hydroxides sludge could be used for removal of Bomaplex Red CR-L from aqueous solutions.	**95.**
69	Journal of Environmental Management/ **Akshaya Kumar Verma et al.**	2012	Decolourisation Coagulation Flocculation	Advance method	1. Dye, Decolourisation, 2. Coagulation, Flocculation, 3. Textile wastewater	Bhubaneswar	1. chemical coagulation/flocculation technologies for removal of colour from textile wastewaters.	**96.**
70	Desalination/**Luqi ng Qi et al.**	2011	Study the optimal ozone dosage, combination of ozone with BAF as membrane pretreatment	Biological aerated filter and Reverse osmosis	1. Ozone, Biological aerated filter, 2. Reverse osmosis, Reuse, 3. Concentrate stream	China	1. Feasibility of reusing the secondary effluent of a textile industry treatment plant as water resource, using the combination processes of BAF with ozone as a pretreatment, and with reverse osmosis for the final step unit.	**97.**
71	Desalination/ **Meihong Liu et al.**	2011	cross-flow filtration system	Nanofiltration Reverse osmosis	1. Textile effluent, 2. Nanofiltration, 3. Reverse osmosis, 4. Water reuse, 5. Wastewater treatment	China	1. Evaluate and compare the effectiveness of reverse osmosis (RO) and nanofiltration (NF) 2. membranes in the treatment of biologically treated textile effluent.	**98.**
72	Powder Technology/**Ilyes Jedidi et al.**	2011	Thermal analysis	Membrane separation method	1. Mineral coal fly ash obtained fromcoal-fired power stations could be also a good material to make low cost membranes.	California, USA	1. Ceramic fly-ash microfiltration membrane applied to the clarification and the decolouration of the effluents coming from the dying industry.	**99.**
73	Desalination/ **Emna Ellouze et al.**	2012	Nanofiltration, Microfiltration	Membrane separation method	1. Textile industry wastewater 2. Coagulation–flocculation 3. Treatment combination 4. Microfiltration 5. Nanofiltration	Tunisie	1. use of Nanofiltration as a post treatment after Coagulation– 2. flocculation used to treat textile water.	**100.**

74	Desalination/ **I. Borsi et al.**	2012	the ultrafiltration	Membrane separation method	1. Hollow fibers, Modeling membrane fouling,	Italy	1. efficiency of the ultrafiltration process for the treatment of secondary effluents to be reused in wet textile industries.	**101.**
75	Water Research/ S**huying Cheng et al.**	2012	Nanofiltration	Membrane separation method	1. Nanofiltration, 2. Positive charge, 3. Self assembly, 4. Dye, Wastewater	UK	1. Nanofiltration membrane for the treatment of textile industry 2. wastewaters	**102.**
76	Bioresource Technology/ **Tim Robinson et al.**	2001	Chemical, physical and biological treatments	decolourisation	1. Textile dyes; 2. Chemical, physical and biological treatments; 3. White-rot fungi; 4. Solid state fermentation (SSF)	UK	1. current available technologies and suggests an e€ective, cheaper alternative for dye removal and decolourisation applicable on large 2. scale.	**103.**
77	Chemical Engineering Journal/ **Bahadır K. Körbahti et al**	2011	Electrochemical treatment	response surface methodology (RSM0	1. Electrochemical treatment, 2. Binary mixture, Acid dye, Reactive dye, Copper, Nickel	Turkey	1. Electrochemical decolorization of textile dyes and removal of metal ions from textile dye and metal ion binary mixtures.	**104.**
78	Journal of Hazardous Materials/ **J. Basiri Parsa et al.**	2009	Decolorization Kinetics	Electrochemical oxidation	1. Electrochemical oxidation 2. Direct blue 71, 3. Decolorization 4. Kinetics	Iran	1. two types of electrochemical reactors for the treatment of simulated wastewaters containing Direct blue 71 azo dye	**105.**
79	Journal of Hazardous Materials/**Dhawal P. Tamboli et al.**	2010	Decolorization experiment	Biological treatment	1. Decolorization, 2. Biological treatment, 3. textile dye	Maharashtra	1. Potential of Sphingobacterium sp. ATM to decolorize and degrade textile dye.	**106.**
80	Journal of Cleaner Production/**Palani vel Sathishkumar et al.**	2012	Bench scale studies	Adsorption process	1. Jatropha curcas 2. Agro-industrial waste 3. Activated carbon 4. Remazol Brilliant Blue R 5. Adsorption isotherm	Tamil Nadu, India	1. agro-industrial waste J. curcas pods were used for the activated carbon the preparation to remove reactive dye.	**107.**
81	Bioresource Technology/	2012	aerobic bio-contact oxidation	biological process	1. Archaea, Bacteria, 2. Denaturing–gradient gel electrophoresis 3. Fungi microbial community, 4. Printing and dyeing	China	1. dynamics of bacterial, fungal and archaeal populations in two-stage biological processes of a full-scale printing and dyeing wastewater treatment	**108.**

					wastewater		system	
82	Journal of Environmental Science and Health	2003	Adsorption	Ion exchange method	1. Sepiolite; Zeolite; Reactive azo dyes; Modified sepiolites and 2. zeolites; Adsorption.	Bulgaria	1. adsorptions of three types of reactive dyes onto natural and modified sepiolite and zeolite have been investigated	**109.**
83	Journal of Chemical Technology and Biotechnology/ **B Armagˇ an et al.**	2003	Adsorption	Ion exchange method	1. zeolite; clinoptilolite; 2. reactive dyes; 3. organozeolite; 4. adsorption	Turky	1. removal of reactive azo dyes by natural and modified zeolites	**110.**
84	International Biodeterioration & Biodegradation/ **Daiyong Deng et al.**	2008	dye decolorizing microorganism	Biological process	1. Broad-spectrum 2. Bacillus cereus strain DC11 3. Decolorization and degradation 4. Comparative analysis	China	1. Decolorization of anthraquinone, triphenylmethane and azo dyes by a new isolated Bacillus cereus strain DC11	**111.**
85	International Biodeterioration & Biodegradation/ **Satyendra Kumar Garg et al.**	2012	Culture conditions	Dye decolorization	1. Decolorization, FTIR 2. GCeMS analysis, Orange II 3. Pseudomonas putida, Textile effluent	Uttar Pradesh	1. study the effect of various cultural and nutritional conditions on decolorization of extensively usedmonoazo dye orange II in minimal salt medium,	**112.**
86	International Biodeterioration & Biodegradation/ **Mostafa M et al.**	2009	Spectroscopic analysis	Biologycal method	1. Algae, Azo dyes, 2. Azo dye reductase, 3. Biodegradation	Egypt	1. Biodegradation of dyes by some green algae and cyanobacteria	**113.**
87	Electrochimica Acta/ **S. Senthilkumar et al**	2012	Combined electrochemical and biological oxidation	Electrochemical, oxidation	1. COD removal, 2. Colour removal, 3. Dye effluent, 4. Electrochemical, 5. oxidation, Procion scarlet	Tamilnadu, India	1. To evaluate the COD reduction and colour removal of dye effluent with individual, combined and integrated process of electrochemical and biological oxidation.	**114.**
88	Resources, Conservation and Recycling/ **Ilda Vergili et al.**	2012	Techno-economic analysis	Integrated membrane processes	1. Integrated membrane processes, 2. Membrane fouling, 3. Benefit/cost analysis, 4. Techno-economic analysis	Turkey	1. zero liquid discharge approach 2. can be used in processing textile dye bath waste streams using integrated membrane processes.	**115.**
89	**C.M. Carliell et al**	1995	Anaerobic	Kinetic study	1. Microbial decolourization,	Italy	1. Microbial decolourization of a	**116.**

			decolorisation		2. azo dye, anaerobic		reactive azo dye under anaerobic conditions	
90	FEMS Microbiol. Lett/ **G.S. Heiss et al.**	1992	Degradation of xenobiotics	decolorization	1. Azo-dye decolorization; Degradation of xenobiotics; 2. DNA cloning; 3. Rhodococcus ; Nocardioforms	South Africa	1. Cloning of DNA from a Rhodococcus strain conferring the ability to decolorize sulfonated aze dyes	**117.**
91	Bioresource Technology/ **Ivana Eichlerova et al.**	2006	Static cultivation	Decolorization	1. Decolorization, 2. Dichomitus squalens, 3. Manganese peroxidase, 4. Ligninolytic enzymes,	South Africa	1. ability of the white rot fungus D. squalens to decolorize different synthetic dyes	**118.**
92	Bioresource Technology/ **Liang Tan et al.**	2009	Decolorization	biological process	1. Decolorization, 2. Azo dye, 3. Salinity, Metal ions, 4. Microbial community	China	1. decolorization of Reactive Brilliant Red X-3B wastewater by the biological process coping with high salinity and metal ions	**119.**
93	Journal of Hazardous Materials/ **Daizong Cui et al.**	2012	Decolorization assay	biological process	1. Azo dye, Decolorization 2. Bacterial consortium, 3. Identification, 4. Microbial community	China	1. comparative studies on the ability of two consortia (AE and AN) to decolorize different azo dyes under aerobic and anaerobic conditions.	**120.**
94	Resources, Conservation and Recycling/ **Antônio Augusto Ulson de Souza**	2010	Mathematical model, Description of the process,	Optimization process	1. Employing the reuse of aqueous streams which are currently sent to the final treatment station.	Brazil	1. Methodology based on the water source diagram (WSD) method was developed, taking the fabric flow as a reference and applying the concept of pseudo-concentration at the inlet and outlet of the tank units of the continuous washing process.	**121.**
95	Applied Microbiology Biotechnology/ **Rajaguru, P et al.**	2000	Anaerobic-aerobic treatment method	Biological treatment	1. Aerobic condition, 2. reduction of dye orange G, 3. isolation of bacteria	Coimbatore, India	1. Maximum degradation of Azo dye by using Anaerobic-aerobic method.	**122.**
96	World Journal of Microbiology & Biotechnology/ **Pradeep Verma,**	2003	Decolourization	Biological treatment	1. Decolourization, 2. laccase, 3. manganese peroxidase, 4. Serratia marcescens	Gujurat, India	1. dye-decolourization of the bacterium Serratia marcescens efficiently decolourized dyes.	**123.**

	and Datta Madamwar							
97	World Journal of Microbiology & Biotechnology/ **O. Adedayo et al.**	2004	biodegradation	Biological treatment	1. Azo dyes, 2. biodegradation, 3. Pseudomonas, 4. textile wastewater, Vibrio	Canada	1. Decolourization and detoxification of methyl red by aerobic bacteria from a textile wastewater.	**124.**
98	Journal of Environmental Management/ **Zeynep Eren**	2012	Ultrasonic treatment	Decolorization	1. Ultrasound, Remediation 2. Dye, Decolorization, Mineralization	Turkey	1. use of ultrasound with biochemical, electrochemical, ozonation, photolysis, photocatalysis and Fenton processes for the degradation of mostly textile dyes and dye bath.	**125.**
99	Chemosphere/**Rey-May Liou et al**	2005	Oxidation catalyst	Oxidation	1. FeIII-resin catalysts; 2. Catalytic oxidation; 3. Phenol; 4. Hydrogen peroxide	Taiwan	1. FeIII supported on resin as an effective catalyst for oxidation was prepared and applied for the degradation of aqueous Phenol.	**126.**
100	Agric. Food Chemestry/ **Lingjun Kong And Ann T. Lemley**	2006	Kinetic model	Anodic Fenton treatment	1. 2,4-D; pesticides; 2. degradation; soil; 3. Fenton reaction; 4. hydroxyl radicals; 5. acid	New york	1. Anodic Fenton treatment (AFT) has been shown to be a promising technology in pesticide wastewater treatment.	**127.**
101	Journal of Photochemistry and Photobiology/**Bhawna Sarwan et al.**	2012	heterogeneous photocatalysis	hydrolysis method	1. BiOCl catalyst, Neutral red 2. Degradation, Mineralization 3. Toxicity reduction	Ujjain, India	1. photocatalytic degradation and toxicity reduction of textile dye using synthesized BiOCl photocatalyst has been successfully carried out.	**128.**
102	Desalination/S. **Karthikeyan et al.**	2011	Preparation of electron rich activated carbon matrix, pre-treatment of wastewater,	Physico-chemical analysis of the wastewater	1. Heterogeneous Fenton oxidation, Textile wastewater, 2. Mesoporous activated carbon, 3. Homogeneous Fenton oxidation	Chennai	1. Treatment of textile wastewater by homogeneous and heterogeneous Fenton oxidation processes	**129.**
103	Applied Catalysis B: Environmental/ **Ricardo Salazara**	2012	Solar pre-pilot plant	Chemical oxydation	1. Anthraquinonic dyes 2. Boron-doped diamond anode 3. Metal catalysts	Spain	1. solar photoelectro-Fenton (SPEF) process with Fe2+ and Cu2+ as metal co-catalysts and	**130.**

	et al.				4. Solar photoelectro-Fenton 5. Wastewater treatment		its application to the treatment of industrial textile dye.	
104	Journal of Hazardous Materials/ **J. Kochanya and E. Lipczynska-Kochany**	2009	Fenton treatment	Struvite precipitation	1. Landfill leachate, Struvite precipitation, Fenton reagent, 2. Respirometry	Canada	1. leachate from an active municipal landfill	**131.**
105	Journal of Saudi Chemical Society/ **N.F. Ali and R.S.R. El-Mohamedy**	2010	Fungi decolourization	Microbial Decolourization	1. Fungi; Decolourization; 2. Waste water; Reactive dyes; 3. Acid dyes	Egypt	1. Six fungal were used for decolourization activities of some acid and reactive dyes.	**132.**
106	Process Biochemistry/ **Myrna Solís et al.**	2012	Biosorption	Advanced Oxidation Processes, Microbial Fuel Cells	1. Microorganisms, Azo dyes 2. Decolouration, Degradation 3. Biosorption, Toxicity	Mexico	1. microbial degradation and biosorption are cost-effective methods for dye removal	**133.**
107	Chemical Engineering Journal/ **Hrvoje Kusic et al.**	2006	AOP experiment	advanced oxidation processes	1. Phenol; AOP; 2. UV irradiation; 3. Ozone; 4. Mineralization	Croatia	1. Comparative investigations of the efficiency of several ozone- and/or UV-based processes for the minimization of phenol as a model hazardous pollutant in wastewater	**134.**
108	Environmental Science and Technology/ **FAISAL IBNEY HAI et al.**	2007	Photochemical degradation	advanced oxidation processes	1. dye wastewater, 2. decolorization, 3. energy and water reuse, 4. hybrid treatment systems	Japan	1. physicochemical and biological techniques have been explored for treatment of extremely recalcitrant dye wastewater.	**135.**
109	Journal of Hazardous Materials/ **Chung-Hsin Wu and Chung-Liang Chang**	2006	Decolorization experiments	Advanced oxidation processes	1. Reactive Red 2; 2. Advanced oxidation processes; TiO2; SnO2; O3; MnO2; 3. Decolorization	Taiwan	1. decolorization of the Reactive Red 2 in water using advanced oxidation processes.	**136.**
110	Chemical Engineering	2010	Acid/base treatment	Adsorption	1. Natural zeolite, 2. Adsorption,	China	1. Natural zeolites as effective adsorbents in wastewater	**137.**

	Journal/ **Shaobin Wanga and Yuelian Pengb**				3. Inorganic ions, 4. Organics, 5. Water treatment		treatment.	
111	J. Environ. Eng /**Annelie Hedstrom and Lea Rastas Amofah**	2008	phosphorus, adsorption, ion-exchange, desorption, zeolite, clinoptilolite, wastewater	adsorption	1. estimate the effects of clinoptilolite grain size and pretreatment of influent wastewater on the ammonium adsorption capacity and clogging of a clinoptilolite filter	Manisa-Go¨rdez, Turkey	2. The ammonium adsorption capacity obtained in this study was similar to other column investigations.	**138.**
112	Waste Management/ **M.I. Panayotova**	2001	Adsorption	Ion exchange method	1. Natural & modified Zeolite, 2. waste water treatment, 3. copper ion removal	Bulgeria	1. Natural zeolite remove cupper from wastewater.	**139.**
113	Journal of Environmental Science and Health / **M. Panayotova**	2000	Adsorption	Ion exchange method	1. Cadmium ions, 2. removal, wastewater, 3. zeolite	Bulgeria	1. Use of zeolite for cadmium removal 2. from wastewater.	**140.**
114	Journal of Environmental Science and Health / **Marinela Panayotova and Borislav Velikov**	2002	Adsorption	Ion exchange method	1. Heavy metals; 2. Wastewater treatment; 3. Natural zeolite	Bulgeria	1. Removal of ions obeyed the kinetic equation for adsorption	**141.**
115	Desalination/ **Nevine Kamal Amin**	2008	UV spectrophotometer	Adsorption	1. Reactive dye; 2. Bagasse pith; 3. Removal; 4. Activated carbon; 5. Adsorption	Egypt	1. Three different activated carbons 2. were prepared used successfully as an adsorbing agent for the removal 3. of reactive orange (RO) dye from aqueous solutions.	**142.**
116	Journal of Colloid and Interface Science/ **V.K. Gupta et al** .	2003	Sorption experiment	Adsorption	1. Adsorption; Activated carbon; Blast furnace slag; 2. Carbonaceous material; 3. Solid waste utilization; 4. Dye removal; 5. Wastewater treatment	Uttaranchal	1. Waste carbon slurries and blast furnace slag have been converted into low cost potential adsorbents.	**143.**

117	Desalination/ **Noureddine Barka et al.**	2009	adsorption kinetic study	Adsorption	1. Natural phosphate; 2. Adsorption kinetics; 3. Adsorption isotherms; 4. Textile dyes	Morocco	1. ability of natural phosphate (NP) to remove textile dyes from 2. aqueous solutions.	**144.**
118	Journal of Hazardous Materials/ **Alok Mittala et al.**	2005	adsorption kinetic study	Adsorption	1. Bottom Ash; 2. Azo dye; 3. Adsorption; 4. Waste materials	Roorkee	1. Waste materials 'Bottom Ash' and 'De-Oiled Soya' were efficiently utilized as adsorbents for the removal of hazardous dye like Amaranth.	**145.**
119	Journal of Hazardous Materials/ **Alok Mittal**	2006	adsorption technique	Adsorption	1. Hen feather; 2. Brilliant Blue 3. FCF; Adsorption; 4. Kinetics;	Bhopal, India	1. Excellent biosorbent for the removal of Brilliant Blue FCF from wastewater.	**146.**
120	Journal of Environmental Science and Health / **M. Panayotova and B. Velikov**	2003	Adsorption	Ion exchange method	1. Heavy metal ions;' 2. Wastewater; 3. Natural zeolite transformation	Bulgaria	1. Influence of Zeolite Transformation in a Homoionic Form on the Removal of Heavy Metal Ions from Wastewater.	**147.**
121	Desalination/ **Lili Lian et al.**	2009	Batch studies	Adsorption	1. Modified bentonite, 2. CaCl2, 3. Adsorption, 4. Congo red, 5. Isotherms, Kinetics	China	1. CaCl2 modified bentonite (BCa2+), a clean and cost-effective adsorbent with a basal spacing of 15.43 Å, was 2. prepared for the removal of Congo red dye from water.	**148.**
122	Journal of Colloid and Interface Science/ **A. Safa Özcan et al.**	2004	Adsorption isotherm studies	adsorption kinetics	1. Adsorption; 2. Acid dye; Kinetics; 3. Bentonite; 4. Thermodynamics; 5. Surfactant; 6. Clays	Turkey	1. Modified bentonite was prepared and tested as an adsorbent for an acid dye removal from aqueous solution.	**149.**
123	Sep. Sci. Technol/ **A. Safa O ¨ zcan et al.**	2004	Adsorption isotherm studies	adsorption kinetics	1. Adsorption; 2. Acid dyes; 3. Clays; Isotherm; Sepiolite; 4. Kinetics.	Turkey	1. adsorption of two acid dyes, namely Acid Red 57 and Acid Blue 294 onto sepiolite.	**150.**
124	Desalination/ **Sh. Sohrabnezhad and**	2010	Adsorption isotherm studies	Adsorption study	1. Mordenite nanocrystal, 2. New methylene blue, 3. Dye removal,	Iran	1. using mordenite and mordenite nanocrystal as an adsorbent to remove new methylene blue	**151.**

	A. Pourahmad				4. Adsorption, X-ray diffraction		from aqueous solution	
125	Water Pollut. Contol/ **R. H. Souther and T. A. Alspaugh**	1957	Pilot-Plant Experiments	Phycal, chemical and biological treatment	1. Pilot-Plant Experiments, 2. textile waste recovery, removal of BOD, 3. colour and alkalinity	Greensboro	1. To reduce the liquid waste load from textile mills.	**152.**
126	Journal of Hazardous Materials/ **Eleni Tsantaki et al** .	2012	Electrochemical oxidation	Advanced oxidation processes	1. Advanced oxidation processes 2. BDD 3. Dyes 4. Electrochemical oxidation 5. Textile wastewater	Greece	1. electrochemical oxidation of textile effluents over a boron-doped diamond anode was investigated	**153.**
127	Environmental Pollution/ **Tania Martellini et al**	2012			1. Polybrominated diphenyl ethers Emission, 2. WWTPs, 3. Deca-BDE Atmosphere	Italy	1. atmospheric PBDEs concentrations 2. within the plant boundary and surrounding area of two Italian WWTPs treating wastewater.	**154.**
128	International Biodeterioration & Biodegradation/ **Nikola Loncar et al** .	2012	FTIR spectrometry analysis	Decolorization	1. Polyphenol oxidase, Potato 2. Decolorization, Reactive dyes 3. Dye effluent	Serbia	1. Potatoes are desirable source for polyphenol oxidase purification of textile dye effluent.	**155.**
129	Chemical Engineering Journal/ **Mayur B. Kurade et al.**	2012	Microbial Type Culture Collection	Biological treatment	1. Decolorization, HPLC 2. Biodegradation, Consortium 3. Biotransformation	Kolhapur	1. Decolorization of textile industry effluent containing disperse dye Scarlet RR was achieved by a developed bacterialyeast consortium BL-GG.	**156.**
130	Journal of Cleaner Production/ **An Derden and Diane Huybrechts**	2013	available techniques (BAT-AEL)	Best available technique	1. Best available technique (BAT) 2. Brominated flame retardant (BFR), Decabromodiphenyl ether (Deca-BDE), Textile wastewater	Belgium	1. to determine the best available techniques for reducing decabromodiphenyl ether emissions from the textile industry via its wastewater.	**157.**

2.2. Study on effective utilization of low-cost absorbent for treatment of textile industrial effluents

Again Mahmoued [159] proposed another wastewater treatment method for coal filter treatment of textile industrial effluents. In this techniques cement-kiln-dust (CKD) and CKD/Coal filters remove colour, heavy metals, organic substances, and turbidity from textile wastewater by hydraulic loading of $1m^3/m^2h$. However, by CKD+Coal filters method, the percentage of removal was more as compared with the CKD filter technique. Saraya and Aboul-Fetouh [160] investigated the process of elimination of acid dyes as well as dye colored by using cement kiln dust from aqueous solution and then the dye concentration was measured using UV-Vis spectroscopy before and after treatment. Whereas, the XRD, Infra-red and differential scanning calorimeter test were also performed to measure the colored residue. Finally, reported that cement kiln dust might be an efficient alternative technique to remove the acid dyes from the textile waste water industries of Egypt. Mostafa et al. [161] proposed the ability of cement by-pass dust (CBPD) a by-product of cement industries can able to decrease the chemical oxidation demand (COD), heavy metals and Total Suspended Solids (TSS) within the acceptable limit from textile wastewater. They also demonstrated in different dose percentages of cement by-pass dust and observed that at 2gm/L dose CBPD was able to remove 75% primary true colour, 33.2% heavy metals, 92.1% TSS and 91.3% COD from textile effluent. Esawy Kasem Mahmoued [162] studied the usefulness of both cement kiln dust and coal filter /cement kiln dust for removal of BOD, COD, heavy metals, colour and turbidity from textile wastewater specifically for weaving and spinning industries of Egypt. Addition of coal filter in CKD was shown better performance as far as removal of heavy metals, colour, turbidity and reduce of BOD, COD as compared with only passing through CKD technique the textile wastewater. However, Mackie et al. [163] studied the physicochemical characterization of six different samples of CKD collected from across North America cement plants and produced calcium hydroxide (Ca(OH)2) slurries for treatment of textile wastewater applications and finally compared these characteristics with commercially available quicklime product. They reported that commercially available quicklime and the slurry made from CKD samples shown equally well, but more quantity of raw material CKD required for acid neutralization of the textile wastewater.

Saraya and Nassar [164] studied on the adsorption of reactive blue 7 [165] dye as generated from textile wastewater using low-cost adsorbent such as CKD by keeping into consideration the use of contact time, dye concentration, and adsorbent dose, respectively. The maximum adsorption capacity of CKD was 100mg/g of CKD at ambient temperature and also reported that the treatment of dye-loaded CKD with different solvents and acids observed that slight amount of dye released in water, methanol, and ethanol due to physically adhesion dye. Whereas in case of acid dye the CKD was dissolved entirely, that may be the interaction of dye molecules with the CKD. Similarly, Shaheen et al. [166] studied the sorption nature of the four divalent metals, i.e. Cadmium, Copper, lead and Zinc in textile wastewater with three different sorbents such as CKD, saw dust and activated carbon [167-169]. Hence, most of the researchers were preferred good adsorbent along with economically viable such as agriculture waste [170], can be used as suitable adsorbent [171-173], tyre char [174], agricultural wastes rice barn [175], bone char [176] and fly ash [177,178] respectively.

They observed that the average material removed from the textile wastewater was 100% Cd was extracted by using activated carbon and CKD, but nearly 75% Cd was eliminated in the sawdust medium. However, the combination of activated carbon and sawdust were not shown efficient sorption in nature for removal of divalent metals from the textile wastewater. Again, another group Refaey [179, 180] studied CKD (a by-product of cement) and activated carbon (obtained from the agriculture waste) as an adsorbent for the removal of cadmium(Cd) and copper (Cu) separately from aqueous solutions. The observed results were indicated that CKD might be used as a low cost and efficient sorbent for removal of cadmium and copper from the textile wastewater as compared with activated carbon. However, Kumar and Porkodi [181] used rubber wood saw dust instead of CKD for removal of Bismarck Brown from aqueous solution by adsorption process. As Bismarck brown was used for hair colorants as well as shoe polish but mixed with wastewater or with the environment may be harmful to human life due to its carcinogenic nature. Hence, rubber wood saw dust can be successfully used as an adsorbent for removal of Bismarck brown from aqueous solution.

Again, Malik[182] studied the adsorption capacity of activated carbon was used for removal of acidic dyes from the aqueous solution, and the activated carbon was prepared from low cost mahogany sawdust and rice husk respectively. The author also observed that the acidic dye not only available in textile wastewater but also from other waste waters such as paper, soap, cosmetics, wax, and polishes, etc. Finally, concluded that saw dust carbon had better adsorption capacity as compared with rice husk and mentioned that adsorption capacity was mainly dependent on contact time, adsorbent dose and pH value of the wastewater respectively [183]. However, Chuah et al. [184] studied only rice husk instead of using both saw dust and rice husk for preparation of activated carbon to remove the acidic dye. They used rice husk for removal of heavy metal as well as dye removal as low cost biosorbent and also predicted that the sorption capacities could be achieved only a specific conditions i.e. treatment process, metal concentration, temperature, contact time as well as pH value. Similarly, Wong et al. [185] considered modified the rice husk (Agriculture wastes or by-products) by different carboxylic acids to improve the binding capacity for removal of Cu and Pb (hazardous materials) from aqueous solution.

Another group of researchers was used fly ash an industrial waste obtained from the thermal power plant for adsorption of reactive dyes from aqueous solutions (Dizge et al. [186]). The fly ash has been used a potential adsorbent for removal of reactive commercial dyes i.e. Remazol Brillant Blue, Remazol Red 133 and Rifacion Yellow HED from aqueous solution. Similarly, Kara et al. [187] studied both adsorbent dosage and particle size of the three reactive dyes, i.e. Remazol Brillant Blue, Remazol Red 133 and Rifacion Yellow HED from aqueous solution using fly ash as an adsorbent under equilibrium conditions. They also recommended that with the increased in adsorbent dose and decreasing in particle size the adsorption capacity of the reactive dyes also increased. Again, Sun et al. [188] reported on both reactive dyes (i.e. Reactive Red 23 and Reactive Blue 171) and acidic dyes. Acid Black 1 [189] and Acid Blue193 from aqueous solution by using fly ash as an adsorbent by taking into consideration of dye concentration, adsorption temperature, time and pH value of the solution respectively. They concluded that for reactive dyes removal the pH value of the solution should be 7.5

to 8.5 and for acidic dyes removal, the pH should be 5 to 6 respectively with optimal temperature 293K for 60mins reaction time.

In another study, Lin et al. [190] reported that removal of basic dye from aqueous solution using fly ash particulates as an adsorbent. In this research work, they treated the industrial waste fly ash with sulfuric acid was used (as low cost adsorbent) for removal of a primary dye (Methylene blue) from the aqueous solution. They also studied the adsorption behavior by using pseudo-second-order model and critically examined the kinetic study, where a positive value of the enthalpy indicates endothermic in nature, and low cost of E suggests the adsorption process might be mainly physical. Ferrero [191] discussed on hazelnut shells and sawdust for removal of methylene blue, basic dye and acid blue 25 from aqueous solution and conducted several sets of experiments about the adsorption capacity of the shells and sawdust. Through the experimental run, the author concluded that hazelnut shells were better adsorbent as compared with the sawdust for removal of methylene blue from the aqueous solution. Ong et al. [192] conducted several sets of experiments for removal of either anionic or cationic dye because of most of the wastewater consisting of a mixture of both basic and acidic dyes. Hence, to remove both the types of dye, authors first chemically modified the rice hull and then used as an adsorbent for removal of acidic dyes. The detailed analysis of the above technique was summarized along with crucial issues raised during the review of the published research as mentioned in Table 2.3.

Table 2.3. Study on effective utilization of low-cost absorbent for treatment of textile industrial effluents

Sr No.	Name of the journal/Author	Year of Publication	List of Experiment Performed	Methodology	Key issues addressed	Location Specific	Remarks	Ref. No.
1	Desalination/ **Esawy Kasem Mahmoued**	2010	hydraulic loading	Aadsorption studies	1. Textile effluents, Seed germination, Cement kiln dust 2. Hydraulic loading, Dyes	Egypt	1. Test efficiency of CKD+Coal filters in removing a colour(97%), turbidity(86%), and organic substance(78%) and heavy metals from textile wastewater	**159.**
2	American Journal of Environmental Sciences/**Mohamed El-Shahate et al.**	2012	spectrophotometric analysis	adsorption equilibrium	1. Waste water, cement dust, 2. acid dye, 3. visual inspection, 4. UV-Vis spectroscopy, 5. AR, AB, COD	Egypt	1. investigate removal of some acid dyes from aqueous solution using 2. cement kiln dust.	**160.**
3	*Ninth International Water Technology Conference/***Hassan Mohamed Mostafa et al.**	2005	DTA analysis	Flocculation	1. Tannery, Wastewater, 2. Kiln Dust, 3. Cement Industry, COD, TSS, 4. Colour, pH, Heavy Metals.	Egypt	1. by-pass kiln dust to decolorize and 2. decrease COD, TSS and heavy metals levels fro textile effluent.	**161.**
4	Desalination/ **Esawy Kasem Mahmoued**	2010	Batch Kinetic Studies	Batch adsorption method	1. Textile effluents, 2. Seed germination 3. Cement kiln dust, 4. Hydraulic loading 5. Dyes	Egypt	1. efficiency of CKD+Coal filters in removing a colour, turbidity, and organic substances and heavy metals from textile wastewater.	**162.**
5	Journal of Hazardous Materials/ **A. Mackie et al.**	2010	Betch-scale experiments	Adsorption	1. CKD, Quicklime, 2. Wastewater treatment, 3. Acid neutralization	North America	1. Physicochemical characterization of cement kiln dust for potential reuse in acidic wastewater treatment.	**163.**
6	International Journal of Research in Engineering & Technology / **Mohamed EL et al.**	2015	Batch Kinetic Studies	Adsorption	1. Cement Kiln Dust, 2. Reactive Blue 7, 3. Isotherm; Kinetics, 4. XRD, FTIR	Cairo, Egypt	1. CKD was used as an unconventional and low-cost adsorbent for the reactive blue 7 dye	**164.**
7	Ecotoxicology andEnvironmental Safety/ **Ingrid Bazin et al.**	2012	UV /visible spectrum deconvolution	Anti-estrogenic activity	1. Textile dyes, 2. Estrogenic activity 3. Anti-estrogenic activity, 4. Industrial textile effluent	France	1. Estrogenicandanti-estrogenicactivityof23 endocrinedisruptingeffectsofthese dyesandwastewatereffluenthavebe	**165.**

							enpoorlyinvestigated.	
8	Water Environment Research / **Sabry M. Shaheen et al.**	2014	Batch Kinetic	Adsorption	1. remediation, contaminated waters, 2. trace elements, 3. byproducts, sorption system.	Germany	1. CKD was the potential as promising sorbents for the effective removal of toxic metals (Pb, Zn, Cu, Cd)from the environment.	**166.**
9	Colloids and Surfaces A/ **Riaz Qadeer**	2007	batch technique	Adsorption	1. Ruthenium ions; 2. Adsorption; 3. Activated charcoal; 4. Nitric acid solutions	Pakistan	1. activated charcoal prove 2. to be an effective adsorbent for the removal of ruthenium ions 3. from nitric acid medium	**167.**
10	Chemical Engineering Journal/ **Vimal Chandra Srivastava et al.**	2007	Batch adsorption	Adsorption	1. Adsorption; 2. Toxic metal removal; Thermodynamics; 3. Temperature; 4. Isotherms;	Uttaranchal, India	1. bagasse fly ash and rice husk ash are adsorbents for the removal of Cd, Ni and Zn from aqueous solutions.	**168.**
11	International journal of hydrogen energy/ **Ya-Chieh Li et al.**	2012	Batch experiments	Adsorption	1. Biohydrogen 2. Dark fermentation 3. Textile wastewater 4. Activated carbon 5. Cation exchange resin	Taiwan	1. textile wastewater was used as a substrate to investigate fermentative hydrogen production performance.	**169.**
12	Chemical Engineering Journal/ **Dalia Khalid Mahmoud et al.**	2012	Batch equilibrium	Adsorption	1. Adsorption, 2. Basic dye, 3. Biochar, 4. Kenaf fibre	Malaysia	1. the ability of the treated kenaf fibre char (H-KFC) to remove methylene blue dye (MB) from aqueous solutions	**170.**
13	FUEL/ **Stephen J. Alien**	1987	Adsorption isotherms	Adsorption	1. adsorption isotherms; 2. dyes	Northern Ireland. UK	1. Equilibrium adsorption isotherms for peat	**171.**
14	Bioresource Technology / **Stephen J. Allen et al.**	2003	Adsorption equilibrium	Adsorption	1. Kudzu; 2. Adsorption; 3. Isotherms; Basic dye	USA	1. equilibrium adsorption of two basic dyes by kudzu has been reported	**172.**
15	Desalination/ **Nevine Kamal Amin**	2008	Adsorbent preparation	Adsorption	1. Reactive dye; 2. Bagasse pith; 3. Removal; 4. Activated carbon; Adsorption	Egypt	1. Bagasse pith, waste from sugarcane, has been used as a preparation of activated carbons.	**173.**
16	Journal of	2010	Production of chars	Adsorption	1. Tire, Char,	Hong kong	1. evaluate the dye adsorption	**174.**

	Hazardous Materials/ **Edward L.K. Mui et al.**				2. Adsorption, 3. Organics, Isotherm		capacity of resultant chars, a series of equilibrium adsorption studies were carried out.	
17	Journal of Hazardous Materials/ **Avinash A. Kadam et al.**	2011	Adsorption	Biodegradation Decolorization	1. Pseudomonas sp. SUK1, Aspergillus ochraceus NCIM-1146, 2. Textile industry wastewater, Chemical precipitate of textile dye effluent 3. (CPTDE), Biodegradation	Kolhapur, India	1. develop consortium using Pseudomonas sp. SUK1 and Aspergillus ochraceus NCIM-1146 to decolorize adsorbed dyes from textile effluent wastewater.	**175.**
18	Chemical Engineering Journal/ **Alvin W.M. Ip, John P. Barford and Gordon McKay**	2010	Adsorption kinetics	Adsorption	1. Adsorption, Kinetics, 2. Reactive Black 5, 3. Bamboo activated carbon, 4. Bone char, 5. Intraparticle diffusion	Hong kong	1. adsorption of a large reactive dye, Reactive Black 5, onto four adsorbents has been studied	**176.**
19	Journal of Hazardous Materials/**N. Dizge et al.**	2008	Diffusion controlled kinetic	adsorption kinetics process	1. Reactive dyes; 2. Fly ash; 3. Adsorption isotherms; 4. External diffusion; 5. Intraparticle diffusion.	Turkey	1. Adsorption kinetic and equilibrium studies of three reactive dyes namely RB, RR and RY from wastewater.	**177.**
20	Journal of Hazardous Materials/ **Deshuai Sun et al.**	2012	Seaparation	Adsorption	1. Fly ash, 2. Adsorption, 3. Anionic dye, 4. Wastewater	China	1. Fly ashwasinvestigated for the removal of RR23, RB171,AB1and 2. AB193 from aqueous solutions	**178.**
21	Water Science & Technology/ **Ahmed A. El-Refaey**	2016	Adsorption kinetic studies,	Adsorption	1. Removal of Cd2þ onto CKD and AC, 2. strong potential of CKD compared to AC for removing Cd2þ from aqueous solutions	Alexandria Egypt	1. CKD can be used as a cost-effective and efficient sorbent for Cd removal in comparison with Activated carbon.	**179.**
22	Alexandria Science Exchange Journal / **Ahmed A. ElRefaey**	2017	Solubility equilibrium estimation	Sorption experiments and analytical methods, Characterization of CKD, Copper	1. Potential of CKD for removing Cu2+ from aqueous solutions within the first 10 min of the batch reaction preceded with no	Egypt	1. copper (Cu+2) removal from aqueous solution by cement kiln dust (CKD) as industrial by-product in cement manufacturing process	**180.**

				removal	effect by temperature or time.			
23	*Int. J.Environmental Technology and Management/* **K. Vasanth Kumar & K. Porkodi**	2009	Sorption experiments, Equilibrium experiment, UV spectrophotometer	Batch equilibrium experiments, Sorption processes (Temp32c)	1. Low cost material, rubber wood saw dust, can be used as an adsorbent for the removal of Bismarck brown from aqueous solution.	Chennai, India	1. Rubber wood saw dust was used as an adsorbent for the removal of Bismarck brown from textile wastewater	**181.**
24	Dyes and Pigments /**P.K. Malik**	2003	Adsorption method was carried out to find physicochemical characteristics	Adsorption experiments, titration methods	1. Activated carbon prepared from low cost materials 2. SDC and RHC have suitable adsorption capacity with removal of Acid Yellow 36 from textile water effluent	Calcutta, India	1. Adsorption capacity of activated carbons, were prepared from low-cost mahogany sawdust and rice husk on adsorption of acid dyes from aqueous solution 2. (Acid Yellow 36).	**182.**
25	Desalination/ **D. Charumathi and Nilanjana Das**	2012	up-flow packed bed column	Biosorption	1. Textile wastewater, Immobilisation, Biosorption, 2. Up-flow packed bed column 3. C. tropicalis, Synthetic dyes	Tamil nadu, India	1. Packed bed column studies for the removal of synthetic dyes from textile wastewater 2. using immobilised dead C. tropicalis	**183.**
26	Desalination/ **T.G.Chauh et al.**	2005	Adsorption process	Measures pH, metal concentration temperature, contact time, competing ions and particle size	1. Used Rice husk as a low cost sorbent for removing heavy metals, textile dye (malachite green & acid yellow 36) aqueous waste streams.	Malaysia	1. Rice husk as an agricultural by-product low cost biosorvent material used as removal of heavy metals &dyes.	**184.**
27	Chemosphere /**K.K. Wong et al.**	2003	Preparation of esterified tartaric acid modified rice Husk, Batch study,	Adsorption experiments,	1. Tartaric acid modified rice husk(TARH) was the highest binding capacities for Cu and Pb removed from aqueous solutions	Selangor, Malaysia	1. Modification of rice husk have been reported in order to enhance the sorption capacities for metal ions(Cu & Pb) and other pollutants	**185.**
28	Journal of Hazardous Materials/ **N. Dizge w et al.**	2008	Diffusion controlled kinetic	Adsorption	1. Reactive dyes; Fly ash; Adsorption isotherms; External diffusion; Intraparticle diffusion	Turkey	1. Adsorption kinetic and equilibrium studies of three reactive dyes namely, RB, RR and RY from aqueous solutions.	**186.**
29	Desalination/ **S. Kara et al.**	2007	Batch adsorption	adsorption kinetics process	1. Reactive dyes; Fly ash; Adsorbent particle size; Adsorbent dosage	Turkey	1. Fly ash, a waste residue generated in a substantial amount in during coal-fired electric power generation, was used as adsorbent	**187.**

							in this study.	
30	Journal of Hazardous Materials/ **Deshuai Suna et al.**	2010	Adsorbents and characterization	Adsorption equilibriums test.	1. Fly ash, 2. Adsorption, 3. Anionic dye Wastewater	China	1. Fly ashwasinvestigated for the removal of RR23, RB171,AB1and AB193 from aqueous solutions	**188.**
31	Dyes and Pigments/ **Roberto Sebastiano et al.**	2012	Micellar capillary electrophoresis	electrokinetic chromatography	1. Textile dyes, Metal complexes 2. Micellar capillary, electrophoresis, REACH legislation, 3. Acid Black and brown analysis	Italy	1. Analysis of commercial Acid Black 194 and related dyes by micellar electrokinetic chromatography	**189.**
32	Journal of Environmental Management/ **J.X. Lin et al.**	2008	Batch adsorption	adsorption kinetics process	1. Fly ash; 2. Methylene blue; 3. Adsorption; 4. Wastewater; Kinetics model	China	1. Acidic treatment of fly ash with H2SO4 typical dye, methylene blue removes from the aqueous solution.	**190.**
33	Journal of Hazardous Materials/ **F. Ferrero**	2007	Fixed bed experiments	Batch adsorption process	1. Dye adsorption; 2. Hazelnut shell; 3. Wood sawdust; 4. Adsorption isotherms; 5. Fixed bed	Torino, Italy	1. Ground hazelnut shells was studied in comparison with sawdust, as low cost adsorbent for dye removal in dye house effluents	**191.**
34	American Journal of Applied Sciences/ **Siew-Teng Ong et al.**	2010	UV-vis spectrophotometer	Adsorption process	1. Adsorption, dyes, 2. batch study, 3. column study, 4. surface morphology, 5. wastewater	Malaysia	1. Modification of rice hull with EDA under the optimum conditions forms as a sorbent(MRH)	**192.**

2.3. Study on effective utilization of textile sludge for preparation of concrete structure in the replacement of cement

Indian textile industry is one of the oldest platforms for the development of dyes on natural and synthetic fabrics. There are huge quantities of varieties of dyes and other chemicals coming out through water and creates a significant problem for society as well as the environment. This wastewater ultimately mixed with river water or mixed with soil water, which eventually causes major problem in society both in liquid and chemically reacts with the environment. Hence, now-a-days the significant challenges are the utilization of textile wastewater either treated the wastewater for reuse in textile industries through different treatment techniques or huge cost was involved for treatment of the waste water. Hence, low cost natural treatment such as cement kiln dust, activated carbon, coal, fly ash and saw dust etc. may be used as an absorbent. At the end of treatment, in one side, the waste water is converted to ordinary water for reuse application in textile industries simultaneously huge quantities of textile sludge is also produced as a byproduct of the textile industry. In India, nearly 70 to 80 million tones of textile sludge are produced as a byproduct every day. Therefore, the disposal of sludge is also challenging job now-a-days the textile industries, because of these waste sludge causes the pollution control board also bans environmental pollution as well as dumping of sludge. Therefore, most of the researchers have developed the alternative use of textile sludge in other section like replacement of certain quantity of cement for construction of the concrete structure, bricks and retaining walls, etc.

Lekshmi and Sasidharan [193] prepared four different concrete cubes with varying percentages of the weight of textile sludge, water, and cement ratio and determine the strength, splitting strength and elasticity modulus of the concrete mixed specimens. They observed that 10% cement replacement of textile sludge at 0.4% water-cement ratio the compressive strength was found to be 29.33MPa, which satisfy the compressive strength of the paver block as per standard. Therefore, ultimately the cost of the concrete structure can be reduced as partial replacement of cement. Similarly, Kulkarni et al. [194] studied the feasibility of the textile mill sludge as a fine aggregate in M:20 grade of concrete. They observed that in conventional concrete mix structure the density, workability, and reduction in compressive strength obtained with the replacement of fine aggregate by textile mill sludge beyond 32%. Therefore, to enhance the compressive strength of the concrete structure, industrial waste such as fly-ash was added in the replacement of cement along with 32 wt.% of textile mills sludge. They noticed that the compressive strength of the prepared concrete structure was slightly decreased with the addition of fly-ash. Balasubramanian et al. [195] and Rahman et al. [196] studied the possible use of textile sludge in structural materials and that to non-structural building materials due the combination ratio of cement and textile sludge was failed to achieve the standard of the structural applications. Therefore, studied for non-structural applications for feasibility analysis as per ASTM standards for nonstructural materials. Similarly, another group of researchers (Sudheesh et al. [197]) proposed the use of textile sludge for replacement of cement and fine aggregate to fabricate paver block, as the only addition of textile sludge for the replacement of cement, the compressive strength shown inferior properties. Therefore, they modified the proportion ratio by addition of another waste, i.e. quarry dust with textile sludge in place of cement. The compressive strength of the new combination of the composites has shown improved on properties by replacing portion cement along with quarry dust and textile dust.

Raghunathan et al. [198] developed a new combination of composites by using existing non-degradable and hazardous waste material mixed with Portland cement replacing sand and related aggregates, due to non-availability of silica sand now-a-days. The proposed composites are having a good quality of reasonably low cost of making of the composite and could be used as an unconventional building material, i.e. synthetic sludge aggregate. Shivanath et al. [199] studied on efficient utilization of textile effluent treatment plant sludge for the replacement of cement in concrete structure (M20 standard). The sludge was collected from the lime treatment of automobile, engineering, and lead battery industries effluents. They prepared the blocks of the mixture of cement and three different weight percentages of sludges i.e. 5wt.%, 10wt.% and 15wt.% respectively. The highest compressive strength was obtained in 5wt.% sludge mixed with cement after 28 days curing. However, Weng et al.[200] discussed only textile industries sludge for manufacturing of low-grade bricks. They mainly concentrated on the percentage of sludge and the firing temperature to improve the quality of the bricks and studied in different weight percentages of the sludge. Finally, concluded that with 20 wt.% sludge incorporated into the brick manufacturing and tested the strength up to 860 to 960 ^{0}C. However, on further increase in the percentage of sludge the strength, water absorption capacity and brick shrinkage was reduced. Sayyad et al. [201] developed new materials by combining two different wastes collected from two various sectors such as textile waste (Sludge) and plaster of Paris waste respectively to improve the sustainability of the material. Again, another group of authors studied the use of textile sludge for the replacement of cement for manufacturing of M30 grades rubber mould paver blocks, where the sludge weight percentage was varied from 0wt.% to 40wt.% at an interval of 5wt.% respectively. The effective weight percentage of manufacturing of paver block was 20wt.% sludge beyond which properties were slowly decreased (Patel et al. [202]). Again, Patel and Pandey [203] collected sludge from cotton dyeing and printing operations hazardous wastes after treatment for reuse in construction materials. The chemical sludge was used along with cement by varying the percentage of sludge from 30wt.% to 70wt.% respectively [204]. The prepared brick was satisfied the BIS standards for the classes of C to K up to the strength of 25N/mm^2.

Sahu et al. [205] studied on sewage sludge pellets for the replacement of sand and mixed with cement in the manufacturing of pavements. In this study, authors were taken all the three sludges such as dried sludge, sludge pellets, and sludge ash respectively for preparation of building materials. They also concluded that with 20wt.% sewage sludge may be used for manufacturing of soft mud bricks, 30wt.% sludge may be replaced with mortar from water and sewage treatment plant for preparation of bricks. João Marciano [206] reported on waste textile trimming fibers mixed with resin /sand aggregate for development of polymer concrete. They successfully studied the flexural as well as the compressive strength of the polymer concrete at room temperature. However, the strength performance was not effective against the function of textile trimmed fiber. Kaur et al. [207] discussed on efficient utilization of textile mill sludge obtained from the effluent treatment plant and observed that with the increased in textile sludge causes reduction in strength of the concrete. After continuous analysis of the study then authors introduced a certain quantity of plasticizer along with textile mill sludge in concrete and reported that the compressive strength of the concrete was 23.55N/mm^2 for M20 grades concrete.

2.4. Study on direct reusing of textile wastewater without further secondary treatment

In India large number of textile industries where dyeing and finishing processes are the principal activity, which requires a significant quantity of pure and excellent quality of water used. As water is also one significant constituent now-a-days in the textile industry, simultaneously the wastewater also creates significant problem for society as well as environment. The waste may be regarding liquid wastes, solid waste or contaminants nature, which is directly, affected the river water and soil water also. Therefore, to reduce these textile wastes, there are lots of researchers going on in the present days. The conventional method is processing of the wastewater in different treatment method and reused it for textile industries further, where costs, as well as time, is the significant parameters. Shaid et al.[208] proposed a cost-effective technique for reuse of textile wastewater without treatment, which reduces the consumption rate of the fresh water as well as treatment time. They studied nearly six different types of rinsing wastewater and used the rinsing waste water for the scouring bleaching of knitted cotton fabric. Finally, they concluded that the weight loss of the scoured bleached sample was nearly 6.53% in fresh water medium and 6.65% in waste water medium after dyed the bleached samples. The reflectance of whiteness was found to be 76.68% and 77.92% respectively for bleached waste water and fresh water samples. Again, Erdumlu et al. [209] proposed an efficient technique for reuse of textile wastewater after primary treatment instead of going through all the three to four treatment processes. The basic treatments such as filtering, ion exchange, airing and pH regulating respectively. They defined in their research that after the effluent water passed through microfilters technique, which is cost-effective and straightforward methodology. The reuse of the water obtained through microfilters is a type of membranes separation technique, removes suspended solids, COD and colour respectively. Whereas, the hardness and conductivity of the effluent can be changed by use of natural mineral like zeolite instead of using advanced membrane separation technique. However, Roohi et al. [210] proposed an alternative method for the use of textile wastewater for irrigation purposes instead of direct use of textile processing industries and reported the nature /strength of soil properties by the use of untreated waste water. The reuse of waste water was applied to different soils for irrigation purposes but repeatedly use of waste water may be affected the soil properties.

2.5. Study on cost-benefit analysis of textile wastewater used in textile industries

Dogan et al. [211] studied on denim textile mill wastewater as per European Union's integrated pollution prevention, and control directive for process and investment cost by applying the wastewater management technique also suggested the alternative water. They indicated on the investment cost, that was the most significant impact due to changes in the exchange rate in all the alternative options. However, operating expense was mainly affected mostly by energy cost to exchange. Chougule and Sonaje [212] primarily proposed the cost-benefit analysis of the wastewater recycling only in wet processing and also suggested that almost all the industries must follow the water management techniques for alternative sources of pure water starting from wet processing to finishing product analysis. In the end, reported that as per ISO-105 and AATCC methods the washing and rubbing fatness of fabric was more satisfactory. Steve Glenn Teal [213] conducted sensitivity analysis for all the treatment processes available till date and developed cost-effective technique based on the present lists of treatment processes by avoiding pretreatment processes of each as every case. The author mainly focused on the decreased use of dye and fabric as far as benefits were considered and also suggested a significant justification for reduction of chemicals during processing, labour, variable overhead as well as fixed overhead. El-Dein et al. [214] discussed the cost analysis of the textile dyes processing and combined H_2O_2/UV, and biological treatment process [36] at higher concentration of reactive textile dye uses. They suggested that H_2O_2 has no absorption capacity but with improved UV technology may be improved the efficiency also biological treatment stage can reduce energy cost to get a higher degree of mineralization [215]. Again, Libra and Sosath [216] suggested the overall cost-effectiveness must be a combination of the capital as well as operating cost. They reported that for ozone treatment the investment cost was much higher whereas, by combining the ozone and biological treatment process was less expensive due to one stage ozone process instead of two different treatment process. Similarly, Tsai [217] studied the energy utilization from the biological treatment process as a preliminary analysis in Taiwan. Their main finding was combustible waste produced from agriculture and industry sectors and further reused as auxiliary fuel. Parveen and Rafique [218] developed an optimal technique without the use of additional chemical at the time of pre and post treatment and also studied the cost-benefit analysis of the proposed efficient method. Cost analysis of the aluminum salt and foil separately and reported that as the aluminum foil was a waste material can be recycled and reused having low operational cost.

The state of Rajasthan consumes 17liters of water per meter of fabric production like in Bhilwara town the fabric preparation capacity is one million meters per days, which consumes 17million liters per day water. Similarly, other parts of the state such as Jodhpur, Pali, Barmer (Balotra), and Jaipur (Sanganer) also consumed equal quantities of water for preparation of fabrics [219]. However, in India, the textile industries alone the water consumption capacity is 200-250m^3/tonne cotton cloth. Again, for the production of man-made fabric, i.e. 120m^3/tone of nylon & polyester produced, whereas, 150 m^3/tone for viscose rayon fibre produced in Rajasthan state only.

In Europe the textile industries annual fresh water consumption was nearly 600 million-m^3 and 90% of the water was used for textile finishing operations, out of which 108 million tons of waste water produced every year but only 36 million tons of chemicals and other auxiliaries removed from the textile wastewater. However, they have successfully developed an alternative technique for reuse of textile wastewater mixed with membrane concentrates followed by treated with the existing biological treatment plant, which can be treated nearly 500m^3/day wastewater and recovered 374 m^3/day water [220]. The summery of various textile industries were used other alternative techniques for textile wastewater treatments as shown in Table 2.4.

Table 2.4. Summary of alternative techniques used in various industry for textile wastewater treatments

Sr No.	Name of the journal/Author	Year of Publication	List of Experiment Performed	Methodology	Key issues addressed	Location Specific	Remarks	Ref. No.
1	International Journal of Advances in Engineering & Technology/ **Sreedevi Lekshmi, Sheeba Sasidharan**	2015	compressive strength	Modulus of Elasticity	1. Textile Sludge, Compressive Strength, Splitting Tensile Strength, Modulus of Elasticity	Thirupur, India	1. investigation on the use of textile sludge in concrete	**193.**
2	Global Journal of Researches in Engineering Industrial Engineering/ **Mr.G.J.Kulkarni et al.**	2012	compressive strength	absorption	1. Textile Mill Sludge, Fly Ash, Concrete, Workability, Compressive Strength	Karnataka, India	1. feasibility of using textile sludge as fine aggregates in M:20 grade of concrete	**194.**
3	Waste Management/ **J. Balasubramanian et al.**	2006	Standard Vicat apparatus	absorption	1. Textile Sludge, 2. Compressive Strength, 3. Splitting Tensile Strength, 4. Modulus of Elasticity	Tirupur, India	1. potential reuse of textile effluent treatment plant sludge in building materials.	**195.**
4	Arab J Sci Eng/ **Md. Mostafizur Rahman et al.**	2016	compressive strength and flexural strength	Absorption	1. Textile ETP sludge 2. Compressive strength 3. Leachability 4. Mortar · Concrete	Bangladesh	1. Characterize and find a potential use of textile effluent treatment 2. plant (ETP) sludge	**196.**
5	International Journal of ChemTech Research/ **Sudheesh.C et al.**	2015	paver blocks	Mechanical mixing	1. determine utilization of the textile sludge as cement replacement material in making the paver blocks	Tirupur India	1. the compressive strength of paver blocks decreases with the increase in the amount of partial replacement of cement with sludge in paver blocks	**197.**
6	International journal of civil and structural engineering/ **Raghunathan T et al.**	2010	Industry Effluent Treatment Plant	Composite prepartion	1. Dyeing Industry Effluent Treatment Plant Sludge, 2. Synthetic Sludge Aggregate, 3. Sand & Concrete	Trichirappalli, Tamil Nadu	1. create a new composite material which can be derived from the already existing non degradable and hazardous waste materials.	**198.**

7	Jr. of Industrial Pollution Control/ **G. Shivanath et al.**	2011	Industry Effluent Treatment Plant	Concrete prepartion	1. ETP sludge, 2. Lime sludge, 3. Use of ETP sludge in concrete, 4. Supplementary cement	Tamil Nadu, India	1. utilize industrial effluent treatment plant (ETP) sludge as partial replacement for cement in M20 concrete.	**199.**
8	Advances in Environmental Research/ **Chih-Huang Weng et al.**	2003	industrial wastewater treatment plant	Brick preparation	1. Brick; 2. Compressive strength; 3. Clay; Metal leaching; 4. Sludge; Utilization	Taiwan	1. Bricks manufactured from dried sludge collected from an industrial wastewater treatment plant were investigated	**200.**
9	Recent treand science and management/ **Karishma Sayyad et al.**	2016	Mechanical analysis	Building material	1. Waste, 2. Plaster Of Paris, 3. Textile Fibre , 4. Reuse , 5. Strength	Maharastra, India	1. The reuse of waste materials can contribute to improve the strength of materials	**201.**
10	International Journal of Constructive Research in Civil Engineering/	2017	Mechanical analysis	Building material	1. Textile Effluent Treatment Plant (ETP) Sludge, 2. Solid Waste Management, Cement, 3. Paver Block, Rubber Mould Paver Block (RMPB),	Gujurat, India	1. textile ETP sludge can be utilized as cement substitute	**202.**
11	American Journal of Environmental Sciences/ **Hema Patel and Suneel Pandey**	2009	Mechanical analysis	Building material	1. Textile industry, 2. chemical sludge, 3. wastewater, 4. construction, 5. reuse, compressive strength	New Delhi, India	1. Using solidification/stabilization indicates that chemical sludge generated from treatment of textile dyeing wastewater has the possibility to be used as the construction material.	**203.**
12	Journal of Hazardous Materials/ **Hema Patela, Suneel Pandey**	2012	X-Ray Diffraction (XRD) and Scanning Electron Microscopy (SEM) examination	Solidification Stabilization	1. Textile industry, 2. Chemical sludge, 3. Solidification 4. Stabilization, 5. Construction	New delhi, India	1. stabilization/solidification of chemical 2. sludge was carried out to explore its reuse potential in the construction materials.	**204.**
13	International Journal of Engineering Science and Technology/ **Vaishali Sahu et al.**	2013	Mechanical analysis	Building material	1. Landfill, 2. sewage sludge ash, 3. sewage sludge pellet, 4. sludge	Gurgaon, Haryana, India	1. Sewage sludge pellets (SSP) has replaced sand in concrete manufacturing for pavements.	**205.**

14	Materials Research/ **João Marciano Laredo dos Reis**	2009	Mechanical analysis	Building material	1. recycling, 2. textile fibers, 3. polymer concrete	Brazil	1. mechanical behavior of polymer concrete reinforced with textile trimming waste was investigated	**206.**
15	International Journal of Civil, Structural/ **Harpreet Kaur Et al.**	2017	Mechanical analysis	Building material	1. Textile industry, 2. chemical sludge, 3. wastewater, 4. construction, reuse, 5. compressive strength	Punjab, India	1. optimum quantity of replacement of textile mill sludge with fine aggregates is 35%, which results 23.55 2. N/mm2 compressive strengths for the M20	**207.**
15	International Journal of Engineering Research and Development/ **Abu Shaid et al.**	2013	Mechanical analysis	Building material	1. Effluent, 2. Wastewater reuse, 3. Groundwater, 4. Environment	Bangladesh	1. Reusing the textile wastewater without any wastewater treatment process in same factory. 2. After using of rinsing wastewater Scouring-bleaching performance are shown in weight loss and reflectance of whiteness.	**208.**
16	AUTEX Research Journal/ **Nazan ERDUMLU et al**	2012	multiple criteria decision making	membrane process	1. Textile effluent, 2. wastewater, treatment, 3. multiple criteria decision making	Turkey	1. Determine the viability of the reuse of effluent water obtained from the textile processes after some basic treatments.	**209.**
17	Journal of Environmental Management/ **Mahnaz Roohi et al.**	2016	Microcosm fabrication	Biological process	1. Textile wastewater. 2. Water extractable organic carbon, 3. Soil respiration, 4. Soil enzymes 5. Soil microbial activity	Pakistan	1. to investigate effects of untreated textile wastewater on soil C mineralization, MBC, qCO2, dehydrogenase activity and some chemical properties of Aridisol which had never received wastewater in the past.	**210.**
18	Water Science & Technology/ **Bugce Dogan et al.**	2010	waterminimisation; wastewater recovery and reuse;	cost-benefit analysis	1. Best available techniques (BAT) 2. cost-benefit analysis 3. cross-media effects	Turkey	1. BAT alternatives such as water recovery techniques and wastewater treatability technologies were	**211.**

					4. IPPC directive 5. textile industry		investigated 2. laboratory-scale tests and their performances were technically discussed	
19	International Journal Of Computational Engineering Research/ **Mahesh B. Chougule et al.**	2013	pilot treatment plant	ISO-105 and AATCC methods, pilot treatment plant	1. Oil and gas removal trap, Slow sand filter, Granular Activated carbon unit (GAC), 2. There was dye saving in wet processing which was additional benefit to industry.	Maharashtra, India	1. By using recycled wastewater were having many benefits: Quality of fabric will enhanced, economical solution to the industries, overcome from the water crisis & Washing and rubbing fatness of fabric observed.	**212.**
20	Agricultural And Applied Economics/ **Steve Glenn Teal, B.S.**	1997	Pretreatment Benefits analysis	Sensitivity Analysis	1. cationic polymer solution, 2. submercerization and mercerization strength sodium hydroxide solutions, 3. chitosan and cellulase enzymes	USA	1. pretreatments would not be cost effective in any scenario considered and the aftertreatments would be cost effective in every scenario	**213.**
21	Journal of Chemical Technology and Biotechnology /**Abdalla Mohey El-Dein et al.**	2006	Reagent and analytical methods	Oxidation experiments	1. Overall removal achieved by combined H2O2/UV and biological treatment of high concentrations of a textile dye, as well as a cost analysis of the process.	Germany	1. Efficiency and cost-effectiveness of H2O2/UV for the decolorization and mineralization of wastewater containing high concentrations of the textile dye Reactive Black 5	**214.**
22	Journal of Hazardous Materials/ **Hua-Wei Chen et al.**	2010	mineralization reaction	Magnetic catalyst	1. Mineralization, 2. Magnetic catalyst, 3. H2O2/O3, 4. Reactive Black 5	Taiwan	1. Prepare a magnetic catalyst (SiO2/Fe3O4) that can be recycled by using an external magnetic field	**215.**
23	Journal of Chemical Technology and Biotechnology/**Jud y A Libra and Frank Sosath**	2003	Rotating disc reactors	Biological treatment	1. textile wastewater; a 2. naerobic decolorization; aerobic degradation; 3. treatment costs	Germany	1. treatment of a segregated textile wastewater containing reactive dyes was investigated in two continuous-flow process trains using ozonation and biological processes.	**216.**
24	Energies/ **Wen-**	2012	Thermochemical	Biological	1. biological wastewater	Taiwan	1. provide a preliminary	**217.**

	Tien Tsai			treatment	treatment; 2. sludge; 3. waste-to-energy; 4. regulatory promotion; 5. benefit analysis		analysis of energy utilization from biological wastewater treatment sludge.	
25	Adsorption Science & Technology/ **Kousar Parveen and Uzaira Rafique**	2017	Synthesis of alumina hybrid	Adsorption	1. Alumina hybrid, 2. adsorption, 3. dopant, isotherm, 4. kinetic	Pakistan	1. cobalt-doped alumina hybrids provides environmental friendly and economical alternative option to the commercial adsorbents for the 2. treatment of textile effluents.	**218.**
26	State Water Resources Planning Department Jaipur	2009	Water Quality, Overexploitation of Ground Water, Water Logging	Environmental Management Guidelines	1. Environmental Issues in Water Sector	Jaipur, India	Awareness programs may be conducted to educate the masses on impact of fluoride	**219.**
27	Desalination/ **De Florio et al** .	2007	Water Quality	biological treatment	1. BAT, T	ROMA, Italy	1. Best available technique for water reuse in textile SMEs.	**220.**

2.6. Study on comparative analysis of hybrid multi-criteria decision making techniques for sustainability of textile wastewater management

Waste-water treatment is one of the most critical and mandatory technology in global policy to bring the environment in a clean and safety culture [221]. Most of the manufacturing as well as mining industries producing vast quantities of waste-water either during cleaning of semi-finishing products or at the time of fabric treatment in textile sectors. In textile industries, different dye solution used to treat fabric and very often the dye contained effluent discharged into open waters without proper treatment [222]. These dyes are synthetic and also exhibit very complex structures making textile waste-water treatment an expensive and difficult task. Conventional techniques such as physical, chemical and biological were reported to use in the treatment of textile waste-water [223, 224]. Apart from various advantages such as effectiveness, less operational time etc., these conventional treatment processes have certain weaknesses such as high chemical cost, complex sludge production, requirement of regular maintenance and high energy demand [221-225]. After studying six different techniques of textile waste-water treatment Nawaz and Ahsan [226] found that no single conventional technique was able to yield treatment efficiency up to 80 %. However, in combination a tremendous increase in their treatment efficiency was registered (94.5%) with lower cost and operational difficulty. Montano et al. [227] reported that the treatment efficiency of a biological process improved drastically if coupled to another process for dye removal from textile effluent. Therefore, the combination of two or more processes for increasing the waste-water treatment efficiency is reported [228-230].

Although physical, biological and chemical techniques have been proposed in different combinations for the efficient treatment of industrial waste-water. Since each combination has certain advantages and disadvantages hence, making it difficult to select most effective treatment technique between the various available options [231-233].This problem can be solved by employing decision-making techniques. MCDM (Multi-criterion decision-making) techniques are the approaches dealing with the selection of most appropriate alternative from a pool of options and widely applied in solving various decision making problems [234-237].

Mahjouria et al. [238] used MCDM and fuzzy logic for selecting the optimum waste-water treatment methodology. They reported that most of the experts discussed mostly on environmental aspects, economic aspects, and technical related issues in a multidimensional approach. These techniques successfully demonstrated an optimal framework through which the plant planners, as well as policymakers, can efficiently manage the generation of waste-water by implementing alternative treatment technology. Akhoundi and Nazif [239] reported different multi-criterion decision-making method namely evidential reasoning approach, which broadly deals with both quantitative and qualitative criterion respectively. These techniques not only discuss only on waste-water reuse but also discuss on treatment technologies for sustainability assessment plants situated at the south of Tehran and Iran. Similarly, Gardas and co-workers [240] discussed three dimensions of sustainability i.e. social, economic and environmental impact to make a balanced growth both textile and other apparel sectors. Santos et al. [241] reported that FAHP (fuzzy analytic hierarchy process) remains the most preferred tool to support sustainable development in various fields. Mahjouri et al. [242] discussed hybrid fuzzy Delphi and FAHP to identify the critical evaluation criterion as well as indicators for sustainability industrial waste-water treatment. Through this decision-making approach, the authors concluded that out of six selected criterion reliability and system efficiency supports shown efficient criterion for development of technological aspects. Sawaf et al. (2018) reported about Turkey textile mills waste-water treatment technologies for sustainability of performance regarding economic, environmental and social impacts. They collected performance scores and their important weights from different stakeholders and then applied MCDM methods. They concluded that out of four different treatment technologies, chemical treatment technology has shown the lowest sustainable alternative as far as textile industry concerned.

2.7. Future scope of research

Insufficient research work has been carried out till date on the direct use of textile wastewater, without any further treatment processes and use of waste sludge for making of building materials such as locking tiles, low-grade bricks by replacing cement. As cement kiln dust also one of industrial waste obtained from cement industries after cement preparation and few researchers have already used this cement kiln waste for treatment of textile wastewater without any further involvement of cost. Similarly, fly ash, quarry dust, plaster of Paris waste, coal, saw dust and activated carbon, etc. can also be used as low cost natural treatment used as an absorbent to improve the sustainability of the construction material for preparation of flooring tiles, solid, bricks and pavement blocks, etc. Therefore, furthermore, research required for detail analysis of the treatment process without going through any artificial chemical treatment process to obtain a clean and pure environment (Figure 2.1). Hence, based on the above literature review number of awareness program is also needed for proper utilization of the textile wastes, due to textile waste not only contains wastes and chemicals but also consists of significant amounts of valuable resources that can be used as a raw material for other industrial applications. However, until day very few textile manufacturing industries have reused the waste water efficiently in textile industries as well as agriculture sectors. Therefore, appropriate technology may be developed to improve the wastewater quality or else an alternative arrangement is required to reuse the wastewater and the sludge. Hence, huge opportunity is there for researchers, manufacturing industries, and society to develop knowledge base networks to create new guidelines for the production of new products from the resulting waste sludge and water. It also recommends that substantial waste industries such as textile waste industries should concentrate more on the quality of chemicals used in the wet process as the strength of chemical may also be affected more the reuse quality of wastewater in the industries. In the end, cost-benefit analysis of the all the treatments and the non-treatment procedure is required for implementation of optimal methodology in textile industries to reduce waste collection and landfill costs, simultaneously these wastes will give direct benefits to consumers and participating enterprises.

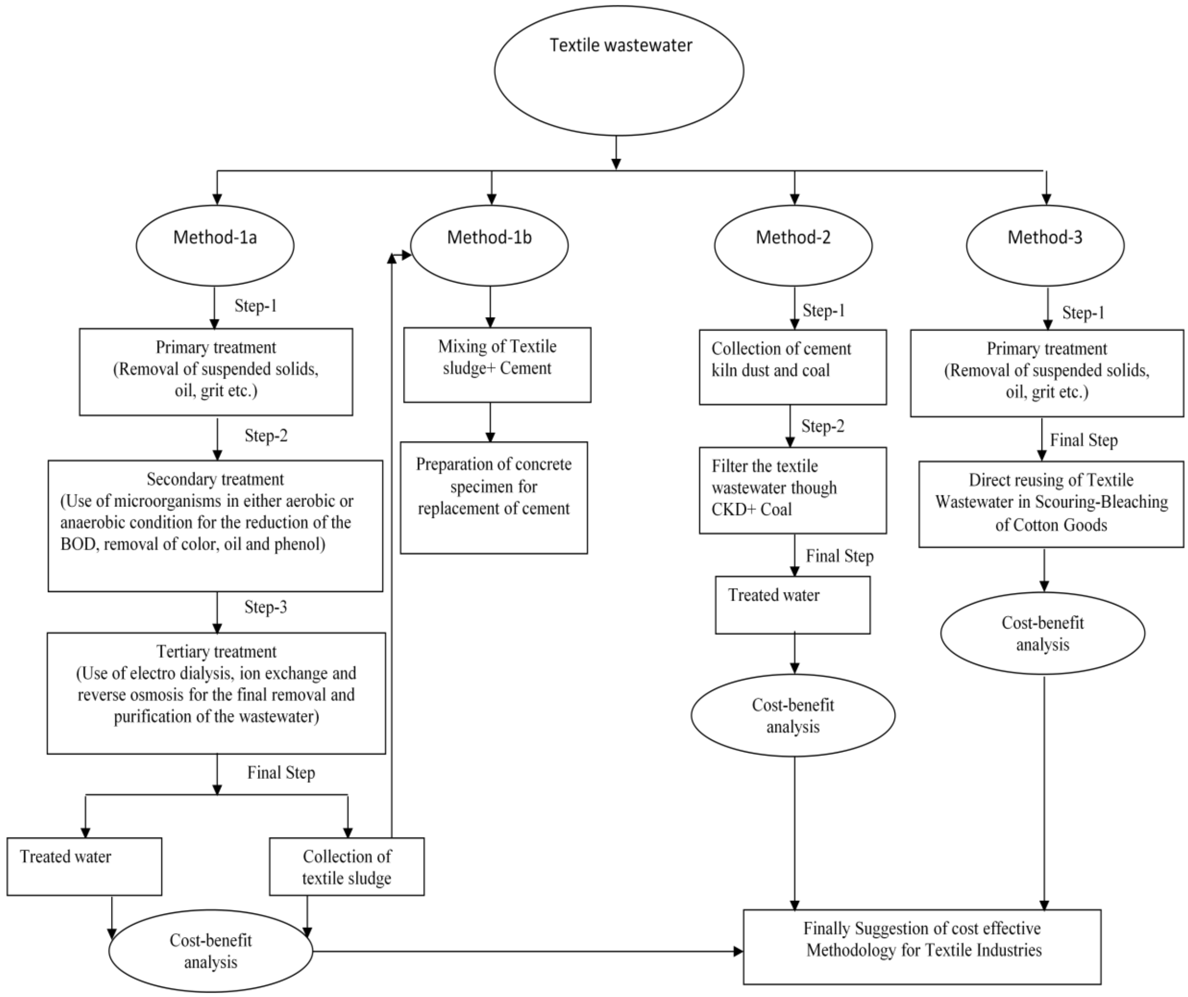

Figure 2.1. Selection effective treatment technique for textile wastewater

2.8. The knowledge gap in earlier investigations

The review of literatures presented above and summarized the following research gaps that need to be paid attention

1. Explores the technical properties of a new product produced from textile waste cuttings in order to determine its usefulness as a new building material. Also there is a need to focus on value addition of sludge comprising recovery of different components and development of commercial products.
2. Evaluate the possibility of recycling water or wastewater treatment sludge as partial or total replacement of water in the production of concretes

3. Modeling and simulation of best case and worst case scenario of sustainable textile waste treatment technology output for future deployment in the State of Rajasthan.
4. A systematic study is required to understand potentiality of utilization of industrial effluent treatment plant sludge as a partial replacement of cement to fabricate low grade concrete structure.
5. A comparative performance analysis and benchmarking of different sustainable technological solutions towards a feasible textile waste management with focus on Rajasthan
6. Region specific research on textile industry may be another area of research. Investigation into the state-of-art technology for the sustainable treatment of textile waste management in the State of Rajasthan.
7. Support the review of alternative water sources for use in industrial clusters and then Work with stakeholders to promote water efficiency equipment and stimulate the cleaner production market
6. There may be area of research which provides evidences about the contribution of industrial/business clusters in developing countries particularly in the context of India.
7. Exploratory cross sectional studies which consider large primary data with multiple parameters (Economic and industry specific) may be an area of research.
8. *Mapping the current state of sustainable textile treatment technology with the existing technology in advanced countries.*

2.9. Objectives of Research

The objectives of this thesis in light of the research questions raised can be summarized as follows:

- Assessment of current and future textile waste generation quantities in India

  The findings from this objective will help decision-makers to review the necessity of achieving sustainability in Indian Textile industry.

  - Data required:

- Survey of wastewater treatment plant (WTP) of textile companies in India and review of Central Pollution Control Board (CPCB) documents on the growth of textile industries in India
- Data on water usage in the different process will be analyzed and quantified.
- Growth statistic shall be used to predict the wastewater generation in the future.

➢ Development of a conceptual model for sustainability of wastewater management in Textile Sectors

- The major contribution of this objective will be to identify and classify the current available system architecture for effective textile waste management in India.
- Documentation of the global best practices in textile wastewater treatment technologies for primary, secondary as well as tertiary treatment and best treated effluent disposal/reuse practices, with special reference to the technologies/practices adopted in common effluent treatment plants (CETP) technologies.

➢ A comparative performance analysis between the sustainable textile wastewater management and performance output through empirical investigation.

- Principle component analysis will be used to benchmark different textile wastewater management for sustainable textile WTT.

➢ Validation of empirical investigation using case study approach in selected Indian textile industry and optimization of treatment process parameters by using integrated hybrid MCDM technique. .

- Here the major contribution will be to identify the limitations and possible deliverables of different textile treatment technology in India.
- Scenarios involving performance under increasingly stringent effluent limits and sustainable targets would be investigated.
- The study will identify and optimize the appropriate textile treatment technology using both qualitative and quantitative factors through Multi-Criteria Decision Making (MCDM) approaches
- Technical quality and sustainable indicators will be developed for the textile wastewater treatment plant

Chapter summary

Textile making industries are one of the major industries in India for the growth of the economy as well as employ the lesser skilled workers to skilled workers. Textile industry produces a massive quantity of textile wastes in term of solid wastes, chemicals, and environment wastes after successful treatment of textile fiber, rinsing of final products as well as from dyes. The treatment techniques followed in textile industries are not cost-effective, and therefore, an alternative treatment technique has discussed for optimizing the treatment technology. The textile wastewater can cause hemorrhage, ulceration of the skin, sickness, impatience, and dermatitis respectively.

The next chapter describes the sustainability of wastewater management in textile sectors: a conceptual framework was used to fulfill one of the objectives of the research work.

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Chapter-3

Sustainability of wastewater management in textile sectors: a conceptual framework

3.0. Introduction

Industrial waste is one of the prime factors in the present world generated from different manufacturing industries and creates a huge problem for the environment as well as produces more quantity of toxic gases. These wastes are either drained to river water or most of the time by different heating techniques transferred to the environment. Hence, most of the countries are more serious about the reduction of wastes and the use of new technology to control the waste generated from industries. The purpose of this study is to develop a conceptual framework for the sustainable development of textile wastewater management by analyzing various factors. The factor includes Labor input in the textile industry, Dyes and additives, Policy implications, Energy consumption, and carbon dioxide emissions, Wastewater treatment and disposal, Improvement of sustainability-related performance, Textile industry productivity, Textile reuse, and recycling, Environmental impact, Economic performance, and Operational performance respectively. Finally, this study also proposes a valuable direction for implementing the desired input factors to obtain the target performance output for the sustainability of textile wastewater management.

3.1. Literature review

The literature review on sustainable textile wastewater management (STWM) mainly focused on policy implication, environment effect, social impact, waste utilization, the productivity of textile industries, sustainability-related problems as well as operational performance, etc. This main study focus is to identify the research gaps from the published literature and the implementation of a conceptual framework to obtain better performance output. To achieve a better sustainable textile sector industry management needs to focus on the following significant factors [244], i.e., Labor input in the textile industry, Dyes and additives, Policy implications, Energy consumption and carbon dioxide emissions, Wastewater treatment and disposal, Improvement of sustainability-related performance, Textile industry productivity, Textile reuse, and recycling, Environmental impact, Economic performance, and Operational performance respectively. Sustainability in Textile wastewater management mainly links to the following main dimensions such as Economic performance, Environmental impact, and Operational performance, respectively as per present desirable.

3.2. Research gap

In the early nineties, Njikam [245] discussed labor market liberalization in manufacturing sectors that includes both skilled and unskilled employment. Finally, the author concluded that firms reforms successfully increased the demand for unskilled jobs and there were no effects on skilled labor demand. Almeida and Poole [246] discussed both labor market regulations law and trade market effects on the labor market in developing country like Brazil's. They also reported that this labor regulation purely relies on Brazil's currency crisis based on administrative data available with them.

It was also reported that for the development of economic and social performance, a sound political framework was needed [247]. Again, the management person from the country like Sri Lanka discussed on conv entional accounting failure strategy effects on workers in textile mills but suggested that the modern industrial culture changes the conventional accounting to modern accounting. The failure in rural culture purely based on kingship obligation, and therefore, Government interference changed the commercial budgeting practices [248]. Nunes et al. [249], discussed the development of new policy for improvement of energy efficiency in the textile sector with the advancement of competitiveness of the enterprises.

In the last two decades, the use of eco-efficiency principle was successfully implemented in various textile sectors. Eco-efficiency not only helps to develop appropriate alternative but is also considered to be a best and promising results in textile sectors of Biella, Italy. Two innovative technologies such as resource efficiency and reducing emissions of water were finally implemented out of six different innovative technologies [250]. Again Gebrati et al. [251] discussed the rejection of toxic substance in the environment that was generated as effluent from textile industries. It was also pointed out that by use of gamma radiation, few elements grows faster (such as nitrogen content) that specifically act as bio-fertilizer helpful for the better growth of plants as it acts as additional nutrients.

Similarly, Bilinska et al. [252] discussed the limitation of one of the treatment technique for textile wastewater. This technique reduced the colors, biological-oxygen-demand (BOD) and chemical-oxygen-demand (COD) etc. from textile wastewater by ozone-based advanced oxidation processes. Martínez [253] discussed the development of energy efficiency in German and Colombian textile industries by using three different alternatives as a case study between the year 1998 to 2005. The energy consumption of different textile industries concerning the production level was also studied and further a relationship was developed between output and energy use. Again, they reported in the second stage of study that in case of German textile sector both capital and energy cost enhanced the gross production energy ratio, but in Colombian textile sector, the importance on the labor, material, and plant capacity utilization improved the gross production energy ratio. The productivity can be improved in any textile sectors by protecting the environment into greener production with the help of stakeholder action.

United State, in the period from 1980 to 1995, the textile sectors improved at a faster rate that ultimately produces huge quantities of textile wastewater that automatically discharges to an environment like river water. Hence, different types of toxicity assessment tool were developed that was beneficial to industries for reduction of wastewater generation [254]. Al-Salman [255] discussed the manufacturing sector in the Kuwaiti by changing the mechanism of both the input-output frameworks along with productivity analysis. However, Zhu et al. [256] discussed greenhouse gas management system in the textile enterprises in China due to increase in global warming phenomena specifically due to textile sectors. Hence, an effective greenhouse gas management system was required to identify the weakness and report the sustainable development criteria to improve their management level. Lenzo et al. [257] explained three different sustainability performance tools to improve environmental impact, performance to achieve a green economy. Considering the detailed literature review, the considerable STWM practices (Variables, sub-variables, performance output and source of items from literature) were reported in Table 3.1.

Table 3.1. Categorization of sustainability of textile wastewater management system

Factors	Sub-factors	Source of items
Labor input in the textile industry	Increase in employee wages	Diodato et al. 2018 [258], Almeida RK, Poole JP. 2017 [246], Aly and Shield 1999 [259], Fedderke and Hill 2011 [260]
	Difficulty in recruiting general staff	Edilberto and Roberta, 2018 [261], Jahanshahloo and Khodabakhshi 2004 [262], Ahmed and Peerlings 2009 [263]
	The low rate of work retention	Krugman, 1991[264], Fujita and Thisse 2013 [265], Duranton and Puga 2004 [266], Mengdi et al. 2017 [267], Wadho and Chaudhry 2018 [268]
	Difficulty in recruiting engineer staff	Mair et al. 2016 [269], Njikam 2016 [245], Almeida and Poole 2017 [246]
Policy implications	The unstable political & social condition	Patrick Conway 2009 [270], Lin et al. 2015 [271], Belkhir et al.2017 [272], Chen et al. 2018 [273]
	Underdeveloped infrastructure	Wickramasinghe and Hopper 2005 [248], Nunes et al. 2015 [249], Hong et al. 2010 [274], Naud and Rossouw 2008 [275], Long et al. 2018 [276]
	Unclear policy management by the local Govt	Wang et al. 2016 [277], Zheng and Shi 2018 [278], Shui et al. (1993) [279]
	Complicated tax procedures	Lin et al. 2018 [280], Martínez, 2010 [253], Paul et al., 2012 [281]
Dyes and additives	Basic dyes, moderate dyes & acid dyes	Rossi et al. 2017 [282], Gebrati et al. 2018 [251]
	Direct dyes & disperse dyes	Paz et al. 2017 [283], Dimakis et al. 2016 [250]
	Vat dyes & sulfur dyes	Babu and Murthy 2017 [284], Abidi et al. 2015 [285], Nadeem et al., 2017 [286], Lu et al.

		2010 [287]
	Azotic dyes & Reactive Dyes	Li et al. 2018 [288]
	Landfill	Saraya and Aboul-Fetouh 2012 [289]
	Agricultural use	Bilinska et al. 2016 [252], Dey and Islam 2015 [290]
Wastewater treatment and disposal	Recovery	Lu et al. 2010 [287], Bhuiyan et al. 2016 [291]
	Building and construction materials	Mostafa et al. 2005 [161], Kumar and Porkodi 2009 [181], Malik 2003[182], Chuah et al. 2005 [184], Wong et al. 2003[185], Shaid et al. 2013[208], Lakshmi and Sasidharan 2015 [292]
Energy consumption and carbon dioxide emissions	Implementation of a certified energy management system	Lin and Zhao, 2016 [293], Hasanbeigi and Price 2012 [294]
	Energy footprint of a production order	Wang 2018[295], Costantini et al. 2018 [296], Lin and Moubarak 2013 [297], Wang et al. 2016 [298]
	Post calculation	Martínez 2010 [253], Lin et al. 2018 [280], Lin and Moubarak 2014 [299]
	Establishing services to support carbon emissions trading	Zabaniotou and Andreou 2010 [300], Cui et al. 2018 [301], Huang et al. 2017 [302], Wang and Ma 2018 [303]
	Regulation influenced technology transfer and R&D activity	Hasanbeigi and Price, 2015 [304], Lin et al. 2011 [305]
Textile industry productivity	Has the follow rate productivity changes	Lin and Zhao 2016 [293], Moore and Ausley 2004 [254], Wadho and Chaudhry 2018 [268]
	Adopt to improve productivity	Al-Salman 2008 [255], Meksi and Moussa 2017 [306], Martínez 2010 [253]
	plan to increase the degree of automation of production	Dimakis et al. 2016 [250], Kusters et al. 2017 [307], Nadiria et al., 2018 [308]
Textile reuse	Reuse(run your own store)	Sandin and Peters, 2018 [309]

and recycling	reuse (sell to non-profits or other businesses)	Dahlbo et al. 2017 [310], Guyer et al. 2016 [311]
	Reuse(sell to a broker)	Silva et al. 2018 [312]
	Recycling	Silva et al. 2018 [312]
Improvement of sustainability-related performance	sludge disposal efficiency	Choudhury, 2017 [313], Gardas et al. 2018 [314], Nimkar Ullhas 2017 [315]
	The efficiency of sludge treatment	Baskaran et al. 2012 [316], Zhu et al. 2018 [256]
	weighted average reagent consumption	Lenzo et al. 2018 [257], Acar et al. 2015 [317]
	Sustainable performance measurement for TWTP	Sawaf and Karaca 2018 [318]
Economic performance	Reduction in cost through improved efficiency	Sawaf and Karaca 2018 [318], Fischer and Pascucci 2017 [319]
	Expand the range of low price product	Brasil et al. 2016 [320], Luthra and Mangla 2018 [321]
	No measures have been taken	Yin et al. 2016 [322], Zhou et al. 2017 [323]
	Increased efficiency through management integration	Martínez 2010 [253], Butnariu and Avasilcai 2014 [324]
Environmental impact	Stricter environmental regulation	Butnariu and Avasilcai 2014 [324], Fan et al. 2016 [325], Koligkioni et al., 2018 [326]
	has air pollution ever affected your health	Resta et al. 2016 [327], Jiang et al. 2016 [328]
	any other effects of air pollution	Shiwanthi et al. 2018 [329], Lo et al. 2012 [330]
	Today job is important as compare to Env.	Hossain et al. 2018 [331], Miller et al. 2018 [332], Muthukumarana et al. 2018 [333]
Operational performance	Brand identity	Seyoum 2007 [334], Lucato et al. 2017[335], Kenyon et al. 2016 [336]
	Goodwill	Fan and Zhou, 2018 [337]
	Old customer relationship	Aziz et al. 2018 [338], Ozturk, 2018 [339]

Quality of the fabric	Prajogo et al., 2018 [340], Kovach et al. 2015 [341], Cámara et al. 2016 [342]

Mwangi and Thuo [343] discussed on only municipal solid waste management techniques and developed a conceptual framework for analyzing various problems associated with solid waste management practices as well as factors. They finally design suitable municipal solid waste management practices for sustainability by adopting a conceptual framework. Similarly, Bernal [344] proposed a conceptual model for wastewater management concept in urban areas by considering the improvement of technology, social and environment impact, economic dimensions respectively. They observed that while implementing the conceptual model, the benefits associated with the decentralization should not be overlooked. Samuel [345] proposed a conceptual model for teaching management accounting to improve the organizational, economic condition through identification of three aspects that theoretically characterize market transactions. This framework helps them not only improved management accounting subject but also given an adequate idea in diverse topics to work logically articulated manner.

- After the identification of the research gap, the STWM literature draws attention to finalizing a comprehensive methodology by correspondingly using main variables and sub-variables. The research gap mainly focused on the following main variables such as policy implication, environment effect, social impact, waste utilization, the productivity of textile industries, sustainability-related problems as well as operational performance.
- It was also observed that limited research on the sustainability of textile wastewater management as far as the Indian textile sector is concerned, and no specific framework is also developed for the improvement of the textile manufacturing sector.

Hence, it is expected that by adopting a perfect conceptual framework to reduce the textile wastes as well as to improve the economic condition of the textile manufacturing sector can be fruitful at the end for sustainable textile wastewater management.

3.3. Research methodology

The research methodology was based on the survey of Indian textile manufacturing sectors to assess the adoption of STWM practices and their impact of sustainable manufacturing performance regarding adopting the conceptual framework as well as proposes of the hypothesis. A schematic diagram of research methodology steps for sustainable development of textile wastewater management is adopted as shown in Figure 3.1. In this study, the data was collected through various literature reviews from the period 1991 to till 2018 due to most of the development in technology mainly focused after in the year 1991.

The selection of research articles was mainly collected from the reputed publishers like Wiley online library, Science direct, Taylor and Francis, Emerald online as well as few available online thesis from different sources (Figure 3.1). The articles are collected based on the following key points such as textile wastes, technology, sustainable textile sectors, reuse of textile wastewater, operational parameters, environmental effect, and sustainable management, respectively. After that summarized the relevant articles as per the STWM practices and additional articles are removed from the downloaded lists.

The major part of this research methodology section was the truncation process that identified more than three industry experts, academicians working in the area of textile waste management, downloaded research articles for the truncation process. During the truncation process, the research articles related to sustainable textile wastewater management were separated. After that the articles are grouped as per STWM practices, i.e., Labor input in the textile industry, Dyes and additives, Policy implications, Energy consumption and carbon dioxide emissions, Wastewater treatment and disposal, Improvement of sustainability-related performance, Textile industry productivity, Textile reuse, and recycling, Environmental impact, Economic performance, and Operational performance respectively.

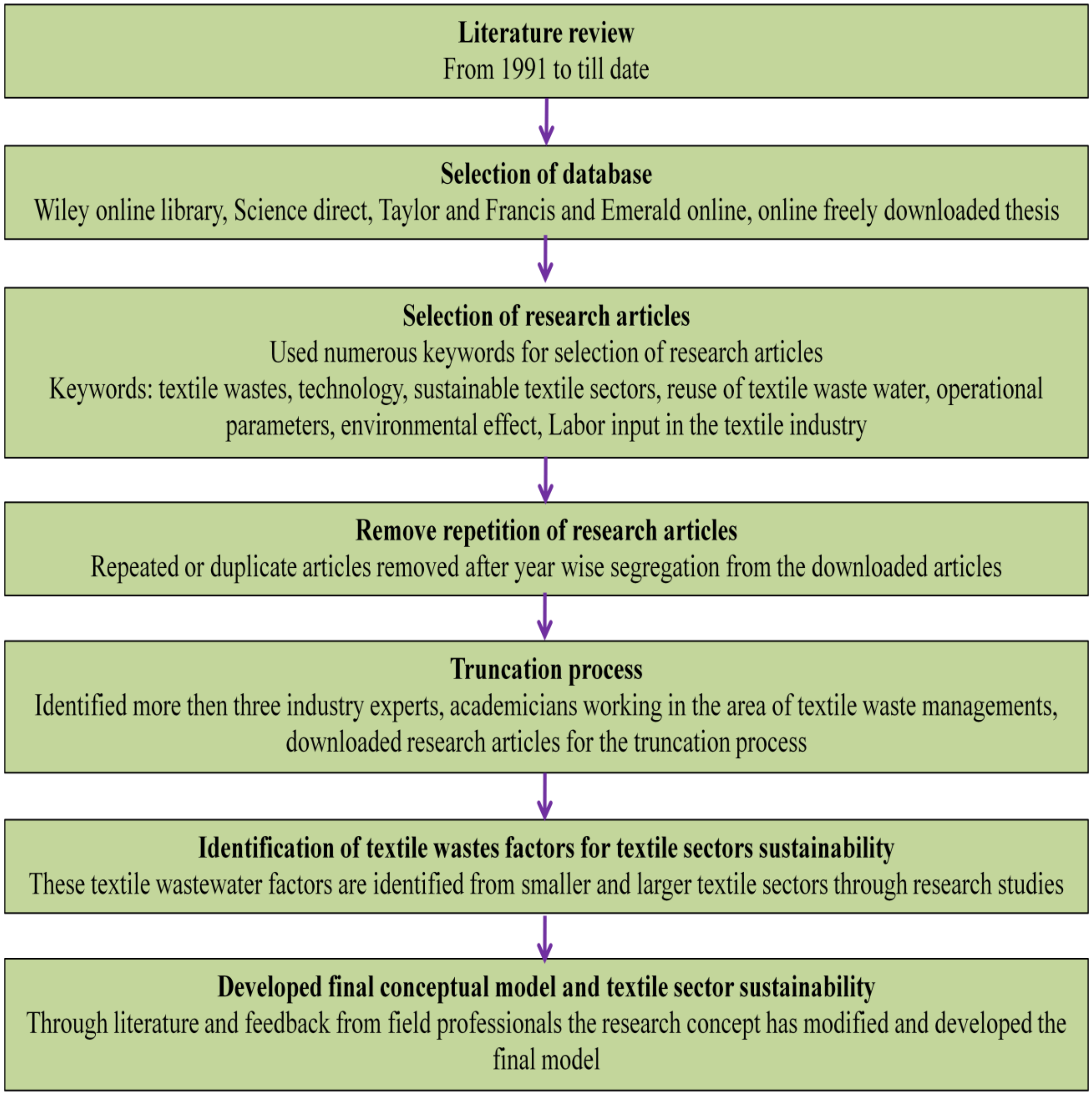

Figure 3.1. Schematic diagram for research methodology steps for sustainable development of textile wastewater management

In the end, developed a final conceptual framework for textile sector sustainability by keeping in view the collected literature and feedback received from field professionals, and these conversations also documented in the conceptual research framework. After, development of the conceptual framework, few senior industry managers are also requested for improvement of the proposed conceptual framework.

Hence, based upon the opinion of individual experts, the formal research framework is confirmed for further analysis.

3.4. Conceptual framework and hypotheses

To get these questions to answer, the authors initially proposed a hypothetical model between the variables and performance measures for better sustainable textile wastewater management (Figure 3.2). Mair et al. [269] defined Western Europe textile and clothing rising demand due to globalized production structure and developed a framework for sustainability between 1995 and 2009. The analysis was based on the effect of the environmental and socio-economic impact on low-labor-cost in a few developing countries with the rise in clothing consumption rate. Finally, it was concluded that by analyzing the implications on results, there might be a more sustainable future for Western European textiles consumption. It was also discussed that the development of technology could significantly improve the economic scale in the country [253].

Hasanbeigi and Price [294] reviewed energy efficiency and energy use efficiency of various textile industries all over the world and also studied few case studies on different textile industries energy saving and other cost information adopted till date. It was reported that all the textile industries need to analyze individually further various economic measures and their applicability regarding the implementation feasibility. The proposed conceptual framework of sustainability of textile wastewater management is to achieve sustainability in textile sectors as shown in Figure 3.2. In the subsequent stages hypothesis are developed that shows a better relationship among STWM practices and output performances.

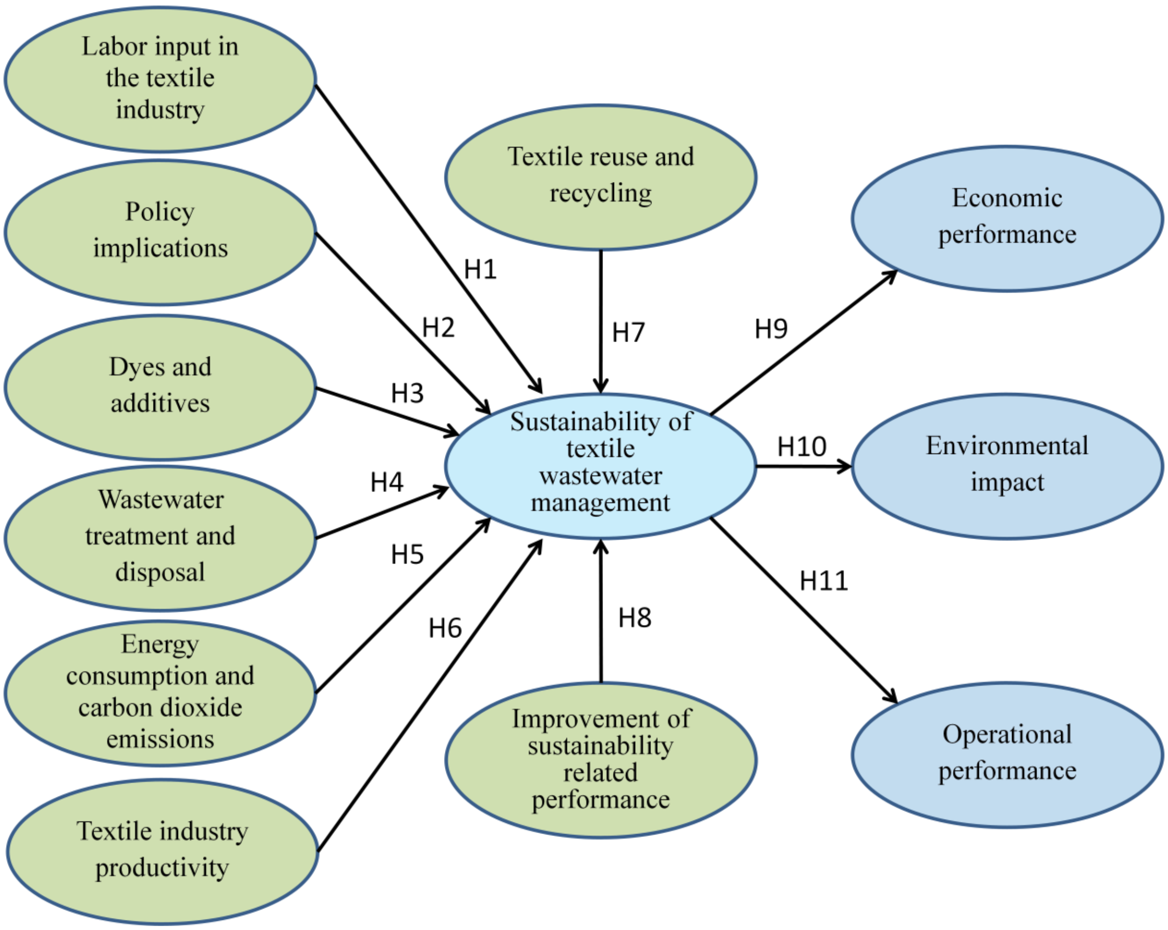

Figure 3.2. Proposed conceptual framework of the relationship between sustainability of textile Wastewater management and performance measures

3.4.1. Labor input in the textile industry

Diodato et al. [258] discussed three types of externalities such as labor, knowledge, and sharing of inputs and observed that agglomeration partnership concept all most all the industries might not get the equal benefit. Therefore, the authors focused on industry-specific coagglomeration a pattern which helps to improve labor and input-output linkages between location and industry for employment growth. Similarly, Almeida and Rocha [246] discussed labor pooling as one of the major agglomeration factors observed from the research data in the period 2004 to 2014[261]. They also studied different theoretical models and reported that productivity growth with agglomeration factor [264-266]. Again, in a developing country like China, the focus was on the mainly discussed on textile industries pollution which directly impacts the environment problem as well as labor working in the industries. As environmental regulation nowadays is a major concern for employment in any Industries and hence, policymakers defined the impact of job and country economic growth main issues. As the practice were most of the textile industries discharge huge quantities of wastewater in rivers as well as dump it in nearby dumping yards [267].

Similarly, Wadho and Chaudhry [268] discussed the implementation of firm innovation, which increased both product innovation and firm performance that ultimately increased labor productivity. They reported that with the increase in 10% innovative sales/ worker directly increases 10% labor productivity as well as labor productivity growth. Again, another group of researchers discussed on Egyptian textile sectors about privatization and surplus labor was one of the indications that increased unemployment. Therefore, Egyptian textile sectors adopted Ray Homothetic production function principle, which ultimately uses more capital as well as labor [259]. A similar situation also happened in other countries like China as well as developing countries where any change in inputs combination directly affects the labor inputs due to changes in economic policy. Hence, Jahanshahloo and Khodabakhshi [262], reported about labor crises in textile industries of China as every year nearly 14 to 16 millions of labors are under the unemployment category, but those labors must be employed. This happened only by changing the input policy that hampered the economic condition of the country.

Henceforth, the country like Brazil adopted de jure labor regulation, which dynamically improved plant productivity and also created new job opportunity with the association of the global market. In South Africa, the manufacturing sector specially discussed on increased labor flexibility, especially rigidity in labor pricing in the period 1970s and at the beginning of 1980s [260]. Again, in the 1990s, an improved form of African labor flexibility was implemented by changing the core policy for reduction of unemployment [260]. Based on the content of the review literature, the following hypothesis is offered (Figure 3.2).

Hypothesis **H1:** Labor input in the textile industry is positively related to firm performance

3.4.2. Policy implications

The US textile firms tried to enter the global market due to plant closure rapidly, market price down, and layoffs. Hence, the major importance was to import the products due to the closed firms, which typically affects the worker's unemployment. Patrick Conway [270] reported that US textile firms adopted a new policy to improve technology progress, trade liberalization, and wage growth. However, Lin et al. [271] discussed how China firms started a political network to built corporate social responsibility by ignoring practical difficulty. Hence, the government subsidies the various factors and allowed foreign investors to improve corporate social responsibility. Again, in China, nearly 176 manufacturing firms integrated their supply chain partners to get excellent performance as compared with the superior firms tie up with the top managers to improve supply chain integration. This concept improved the economic condition, technology changes as well as manufacturing firms performance by the tie-up with top management in China and other countries also [273]. However, the policymakers in the Middle East and North Africa region (MENA) region implemented an important policy to improve the business environment. Shui et al., [293] discussed textile trade liberalization by implementing multi-market displacement model and observed that by implementing the above model no dought there was marginal changes in total demand for U.S cotton but affect cotton growers more on the world market.

The investigation was conducted in all four sectors: social, technology advancement, economic, and political factors to reduce greenhouse emission. Hong et al. [274] reported the implementation of Taiwan energy policy to save energy because of energy crises, specifically in firms like Textile industries. Hence, because of that reason, Taiwan developed self-produced energy, which increased efficiency as well as energy saving capacity. Finally, it was concluded that nearly 94,614 MWh of electricity, 23,686 kl of fuel oil and 4887 ton of fuel coal was saved. Again, Naud and Rossouw [275] discussed the implementation of the new policy for export of textile cloths and products related to textile from China to South African quotas for two years. This was due to the increase in unemployment by nearly 62% from 1995 to 2005.

However, subsequently, it was observed that South African trade policy mostly damaged the domestic market and government was regrettable about policy mistake.

Long et al. [276] identified the sectoral economic interaction in Japan because in traditional approaches, the industrial emissions were severely criticized by-product based perspectives. Their main goal was in direct emission high quantity of emission rate in manufacturing sectors. Individually, agriculture sectors, as well as textile sectors due to these sectors, exceed in indirect emission intensities. Hence, a better emission process was proposed for environmental sustainability along with other factors like chemical pollutions as well as reduction of natural resources. However, Wang et al. [277] discussed climate policy implementation in developing countries called carbon tariffs policy where they produced their textile products and transferred to the other developing countries. This ultimately resulted in better performance in the international market and subsequently examined the policy from time to time. Consequently, each manufacturing company produced the same type of textile products and established a competitive market model for standardization of the price.

Whereas, Zheng and Shi [278] reported on three different issues such as land policy, firm location and firm heterogeneity in Chinese manufacturing firms and observed that the expansion of land supply and land distribution policy show positive impact towards the firm location. Therefore, the local government successfully implemented allocation policy instead of developing more heavy construction. The number of textile industries in China was more significant as compared with other developing countries and was also a significant exporter. Therefore, energy saving was also one of the major issues in China and to save energy Chinese textile manufacturing industries implemented advanced technology for the improvement of energy saving potential along with the reduction of CO_2 emission. They not only modify the manufacturing technology but also simultaneously changed labor productivity, enterprise scale, foreign trade, and electricity prices [280]. Similarly, German and Colombian textile industries also discussed energy efficiency development, which benefits the improvement of production level, output performance, labor productivity, textile products as well as proper energy uses in industries. Based on the content of the review literature, the following hypothesis is proposed (Figure 3.2).

Hypothesis **H2:** Policy implications in the textile industry is positively related to firm performance

3.4.3. Dyes and additives

Dye and additives are the major ingredients to improve the performance of the textile fibers, and because of these dyes, the final cloth image changes drastically as per present customer desire. However, nowadays, huge quantities of synthetic dyes are used as per market demand, and these synthetic dyes are also producing more amount of chemical which is dangerous to human health as well as environment. However, natural dyes are better than synthetic dyes, but the cost is a major factor which automatically increases the price of the cloth. It also affects the market values because the synthetic dyes are naturally toxic, carcinogenic, and have toxicological properties. Rossi et al. [282] discussed the use of natural dyes extracted from production waste product through innovative approach for minimization of waste resources and also exhibiting less toxicity. They used colored liquid wastes collected from the steam treatment of eucalyptus wood and used it to dye cotton, nylon, and other woolen products without any use of mordant. Similarly, Paz et al. [283] reported on the performance of species Bacillus Aryabhattai that degrade commercially available dye and after that also proposed three more dyes studied in different operating conditions. They optimized the process by using central composite rotational design and finally validated with indigo carmine and Coomassie Brilliant blue G-250 (CBB). It was also suggested that the species Bacillus aryabhattai was considered as a novel strain that was an eco-friendly and cheaper procedure as well.

It was suggested that after activated sludge treatment from textile effluent, nearly 50% bacterial activity was decreased and found that bacterial activity mainly depends on contact time as well as the volume of effluent. Belpaire et al. [346] studied different types of dyes used in the different sector, starting from leather industries to textile industries and their toxic nature for our environment. They collected information from the period 2000 to 2009 in different locations that include river, canals, and lakes by using liquid chromatography-tandem mass spectrometry to measure the ultra performance.

Babu and Murthy [284] discussed on the new type of treatment techniques for wastewater collected from textile industries, which can further reduce the toxic effect as well as the permit the use of treated wastewater in auxiliary applications. The study was mainly focused on nanofiltration membranes technique and show better performance than conventional techniques on the removal of dyes from wastewater effluent. However, Abidi et al. [285] discussed on use of natural clay for treatment of dye-effluent because natural clay was able to remove the color from wastewater effluents that usually contains various types of dyes as well as additives. It was found that during the preparation of dyes, a lot of chemicals and salts were used and natural clay can easily absorb the dye containing effluents. Therefore, natural clay was one of the significant alternative treatment techniques for the removal of colors from textile wastewater effluent. Biological treatment was also one of the newest techniques commonly used by textile industries for the treatment of textile wastewater effluents. This was due to the enormous waste generated by textile industries that contain toxic, colors and organic compounds, depending on the production rate of industries, types of fibers used, technology, raw materials, and management system, etc. Hence, biological treatment could able to reduce waste effluents for achieving sustainability [286].

Li et al. [288] reported on the use of direct contact membrane distillation technique for the treatment of dyeing wastewater and removal of related pollutants. It was finally concluded that this method removes a maximum quantity of suspended solids, color, and dispersed dyes with limited energy consumption and show better performance. Wet processing sectors like textile and leather were also facing a lot of environment problem due to the generation of both salts and reactive dyes in huge quantity as compared to conventional processes because of the low resemblance of the dye to substrates with the help of hydrolyzed collagen [281]. Similarly, Lu et al. [287] discussed both biological treatment and membrane technology for recovery of wastewater effluent of textile industries in China. It was observed that nearly 93% removal efficiency of COD, 94.55 color, and 92.9% turbidity were achieved through this technology. Based on the content of the review literature, the following hypothesis is proposed (Figure 3.2).

Hypothesis **H3:** Dyes and additives in the textile industry are positively related to technology performance

3.4.4. Wastewater treatment and disposal

Normal water is one most essential part of every living being for a matter of survival; water is also beneficial for the development of industries extending agriculture sector to the manufacturing sector. However, nowadays, the level of water on the surface is slowly reducing due to improper utilization of wastewater generated from different industries.

Moreover, the municipality, as well as chemical and textile sectors, are the source of major wastages. Therefore, reuse of wastewater is a major concern for every country. The wastewater not only harms the environment but also reduce the country growth in all most all the sectors, this may be because of the deteriorating quality of the water used nowadays. Hence, every government is implementing new regulation for effective utilization of water and reuse of wastewater for different applications again and again to control the environment. Wastewater is generated mainly from municipal sewage, food processing, leather industries, textile industries, automobile industries, paper, and pulp industries, canning industries, etc. There is huge number of sectors where generated wastewater gets mixed with either river water or dumped in different dumping yards. This ultimately creates a number of the health-related problem to human life and creates similar problems to another living being on the earth.

The present work mainly focused on textile sectors waste utilization and its reuse in the textile sectors. The textile industry is one of the major sources of income for most of the developing countries, and most of the unskilled and skilled labors are depending on the textile sectors either directly or indirectly in their life for survival. There are few countries in which the main source of income is through the textile sectors only, and there is no alternative sector for their dependence. Lu et al. [287] discussed on effective utilization textile wastewater in China and reported that reuse of textile wastewater was one of the best alternatives instead of using fresh water as far as cost is concerned. It was observed that through biological treatment and membrane technology, the wastewater recovery was successful due to which nearly 0.25US$/ m^3 can be saved at the time of initial manufacturing. As it will also save the environment, the technique is claimed to be one of the best promising methods to reuse the wastewater for textile treatment plants. Bhuiyan et al. [291] discussed another method for reuse of wastewater in either textile sector or some other sectors. It was reported that by the use of gamma irradiation technique, the dye molecules and organic pollutants available in wastewater could be degraded and then the treated wastewater can be used for dyeing purposes as well as irrigation purposes.

Similarly, Dey and Islam [290] discussed Bangladesh textile wastewater treatment techniques, which reduces huge quantity of waste generated from textile sectors and creates problem to the environment as well as agriculture, workers health, and also damaged the society financial growth. Therefore, the use of one of the basic treatment technique, i.e., physicochemical techniques, was emphasized. Bangladesh government made a specific rule for all the textile sectors to use this technique as a prerequisite for the establishment of the textile industry in this country. Saraya and Aboul-Fetouh [289], reported on the use of alternative treatment technique by using cement kiln dust for removal of acid dye from aqueous solution. The cement kiln dust is also similar solid waste obtained from cement manufacturing plants. In Egypt, most of the textile industries produce huge quantities of textile waste or waste effluents during cleaning and coloring of textile fibers. These wastes were ultimately transferred to the river, which causes a major concern to the environment. Most of the textile industries use different techniques to remove acid dyes, and these procedures were not cost effective. The use of cement kiln dust residue to remove the color dyes from the wastewater effluent is one of the effective techniques. Similarly, Mostafa et al. [161] used an optimal quantity of cement by-pass dust or cement kiln dust for removal of colors as well as reduce other elements like COD, TSS, and some heavy metals. It was reported that the percentage dose of cement by-pass dust should be in the range of 0.5 to 3.5gm/L for better performance as compared with other types of solid wastes.

However, Kumar and Porkodi [181] discussed the use of rubberwood sawdust for the removal of color from dye bearing effluents because such wastewater was challenging to treat by conventional methods. Rubberwood sawdust was used as an adsorbent for extraction of brown Bismarck from aqueous solution, which is carcinogenic to humans as far as health was concerned. In the line of this study, Malik [182] used both sawdust and rice husk as low-cost adsorption for removal of acid yellow 36 this was because of from the low cost adsorbent activated carbon was prepared. It was also concluded that the carbon percentage was maximum in saw dust as compared with rice husk. Similarly, Chuah et al. [184] reported on only sawdust used as low cost sorbent materials for removal of heavy metals and could also remove dye, because in the present methodology removal of heavy materials such as Al, Au, Cr, Cu, Pb, Fe, Mn, Zn and Cd from solution was very expensive procedure. However, Wong et al. [185] discussed on tartaric acid modified rice husk as better sorbent materials due to the highest binding capacities for removal of Cu and Pb. Finally, it was concluded that the pseudo-second-order model shows better sorption capacity than the pseudo-first-order model.

Shaid et al. [208], concentrated more on the effective utilization of the textile wastewater without any further treatment mostly defined as direct use of textile wastewater for the scouring bleaching of knitted cotton goods or fabrics. It was observed that by comparing both freshwater and textile wastewater, the weight loss was marginal, and the reflectance of whiteness was also in a similar result. Lekshmi and Sasidharan [292] reported that nearly 70 to 80 million tones of textile waste are generated every year in Thiruour, India, and the disposal of wastewater is one of the major problems in every part of the country. Hence, now a day these textile wastes were used for construction applications for replacement of cement. The optimal cement and textile sludge ratio were determined as 10:0.4, respectively for better compressive strength, which satisfies the paver blocks standard. Based on the content of the review literature, the following hypothesis is proposed (Figure 3.2).

Hypothesis **H4:** Wastewater treatment and disposal in the textile industry is positively related to technology performance

3.4.5. Energy consumption and carbon dioxide emissions

The development of a country economy depends upon the growth of industrialization and urbanization that in turn, depends on energy. This implies that the energy shortage typically affects the international market and energy security. China government recently promoted energy conservation with emission reduction in textile industries because the most of the textile industries generate much heat during spinning cooling, washing textile fibers, waste gas generated during treatment as well as other sources of heat generated through air conditioner and compressors, etc. Therefore, in order to reduce the generation of heat, energy conservation technology has been implemented to improve energy efficiency, product quality, and ultimately to curb pollution [293].

Similarly, another group of researchers reported on the improvement of energy productivity in any manufacturing sectors need to be changed the technology as well as efficiency factors in a country like China. This may be due to the nominal price of energy as well as low energy taxes in China as compared with other countries. Hence, technological reformation is highly needed to make healthy market competition [295].

Costantini et al. [296] explained on EU employment dynamics to improve energy efficiency both in private as well as public sectors and observed that any sectoral output improvement, investment, activities, and energy efficiency gain shown an adverse effect on employment growth. However, Lin et al. [280] discussed the improvement of energy efficiency in China textile sectors by the development of technology using macroeconomic concept. A model was proposed for the future improvement of energy saving by developing technology, labor productivity, foreign trading, electricity prices with energy intensity. Analysis of the above relationship, they also discussed on energy saving concept and reduction of CO_2 emission in China textile industries by implementing scenario analysis.

Similarly, Zabaniotou and Andreou [300] discussed the use of cotton gaining wastes as a green fuel for improvement of environmental sustainability and the development of alternative energy in textile sectors with the reduction of emissions. Through this technique, one part the waste cotton was effectively utilized for energy production and in second section reduction of the use of heavy fuel oil with nearly 52% of the production of bioenergy for thermal requirements. As in China, the CO_2 emission was nearly half of the total power industry and was also the largest CO_2 emitter in the world. Hence, China's power sector played a significant role in the reduction of the carbon economy by implementing micro and macro policy in power sectors. Ultimately, both the government and power enterprise should take a major role to reduce emission in power sectors [301]. Lin and Moubarak [297] discussed Chinese textile industries potential changes in energy-related CO_2 emission from the period 1986 to 2010 and observed that industrial activities and energy intensity were the main producers of CO_2 emissions. They reported that the increased in CO_2 emission was mainly increased textile sectors nearly 5% annually from the period 1986 to 2010 along with 4% increased in energy consumption.

Again, the same group forecasting the CO_2 emission in different scenarios for the reduction of CO_2 emission in the Chinese textile industry by implementing the Johansen co-integration technique. They also clearly concluded that the energy cost, energy substitution, labor productivity as well as technology play a major impact on the carbon intensity [299]. Huang et al. [302] explained that the reduction in greenhouse gas emissions was a significant challenge in textile industry sectors because China was the sixth largest energy consuming industry sector. This was due to an increase in industry sectors in China that ultimately increased greenhouse gas emissions. Wang and Ma [303] reported on Jiangsu province, carbon dioxide emission strategy from the period 2000 to 2014 and analyzed the CO_2 emission using Tobit model by taking into account four variables, i.e. foreign trade, R & D expenditure, industrialization level, and energy consumption structure. They also explained the development of new technology during the said period at a growth rate of 1.5% per year. However, technical and scale efficiency were shown declined in order.

Whereas, Wang et al. [277] discussed both energy consumption and carbon dioxide emission of industries from the period of 2003 to 2012 of Tianjin province and observed that 9.11% annual growth was noticed along with 53.17% decrease in emission rate. However, to improve the energy efficiency and reduction in carbon dioxide emission of Tianjin's energy consumption during the period 2008 to 2012, it was suggested that development of green and low carbon industries could reduce emission rate and improve energy conservation drastically. Based on the content of the review literature, the following hypothesis is proposed (Figure 3.2).

Hypothesis **H5:** Energy consumption and carbon dioxide emissions in the textile industry is positively related to economic performance

3.4.6. Textile industry productivity

Textile industries mainly depend on a large volume of water for printing and cleaning, electricity as well as fuel and then discharging textile wastewater effluent, greenhouse gas, etc. With the increased consumption rate of textile products, the textile production rate also increased symmetrically along with an increase in energy use. Hence, keeping in view the above limitations, automatically textile manufacturing sectors introduced emerging technologies for the workers, reduction of pollution improvement of energy and recycling of wastewater for further utilization in textile industries [304]. Similarly, Lin et al. [305] also reported that China had given more significance to manufacturing activities, which increases the textile firm productivity. The calculated the Ellison–Glaeser (EG) index was around 0.00019 from the available data collected in the period 2000 to 2005, and it was concluded that industrial agglomeration enhanced the productivity. Lin and

Zhao [293] discussed energy efficiency with the change in technology and energy rebound effect in Chin's textile industries by implementing new policies. Therefore, by implementing these new policies, energy consumption and effective prices can be reduced with the increase in energy services. The improvement of energy was verified through the rebound effect in the textile sectors (20.991%) that ultimately improve the productivity of the sectors.

The main outcome of the proposed methodology was to create a relationship between the sectors and the development of new technology in manufacturing industries. It was also demonstrated that with the change in technology, the initial investment was increased, but import capacity was successfully enhanced. Dimakis et al. [250] provided a greener and sustainable development concept to measure the eco-efficiency that suitably measured the product or services lifecycle. Hence, eco-efficiency guides are used for the improvement of perfect metrics for evaluation of perfect alternative solutions. The development of technology not only improved industry productivity but also controls the production of wastes in the industries. Nowadays, environmental sustainability is one of the major factors for almost all the manufacturing industries, specifically textile industries. This is due to the generation of huge quantities of waste, starting from solid waste to water waste. Hence, research on textile engineering is highly innovative as far as an industrial process is concerned because the wet textile process was highly expensive in terms of energy, water, textile materials degradation and wastewater treatment respectively [306].

Kusters et al. [307] discussed the implementation of digital operations technologies and Industry 4.0 solutions in Textile industry in Germany. It was concluded that by implementing a value chain structure starting from order to deliver, the manufacturing sector becomes smarter and also an enhancement in product development within the factory based on the customer requirement. This study was entirely different from other studies in the US industries for improvement of productivity growth, demand and production structure. In US industries they mainly focused on the importance of modern infrastructure such as latest broadband technology network that easily transfers the information related to the changing in technology, production function in other sectors as well as other parts of the country [308]. Similarly, Wadho and Chaudhry [268] reported product innovation and its impact on a firm's performance. Information was collected through survey homogeneous data collection technique in Pakistan by obeying multi-stage structural modeling. It was observed that by implementing the above model, the innovation sale was increased by 10% per worker simultaneously increased labor productivity and growth by 10%. This helps in the improvement of knowledge flows from foreign customers to firm decision to innovation. Finally, it was concluded that larger firms invested more in innovation that increased organizational sales and automatically improved productivity.

Martínez [253] discussed three different alternative indicators for measurement of performance regarding energy efficiency in German and Colombian textile sectors in the period 1998 to 2005. The results show that by changing in energy efficiency between these two countries, the German textile sector, capital, and energy variables improve the gross production and energy ratio whereas, in Colombian textile sector improve the gross production and energy ratio by putting in different variables such as labor, material, and plant capacity utilization respectively. Based on the content of the review literature, the following hypothesis is proposed (Figure 3.2).

Hypothesis **H6:** Textile industry productivity is positively related to firm performance

3.4.7. Textile reuse and recycling

The textile product gradually increased with the increased demand in the world due continuously growth in population and the development of economic conditions. Therefore, on one side, the demand rate is unanimous increased, and on another side, the pollution rate is also increased. Most of the wastes are generated during the cleaning of fibers and treatment time, which is ultimately discharged into river water and or kept in artificial dump peat that subsequently spread into the environment. Therefore, textile sectors took several measures to improve the treatment process, improve the technology and reduce the waste effluent for development of effective manufacturing process that gives rise to more substantial environmental impact to the society as well as improve the textile sectors economic growth. Therefore, based on the above analysis Gustav and Peters [309] discussed on the recycling and reuse of textile wastewater for further development of the textile sectors by using advanced technology to recycle the wastewater so that the same water could be reused for treatment of textile fibers as well as some other applications. The major benefit behind the above discussion was the reduction of wastes from water to textile products. In Finland, the textile wastes increased to a large extent with the increase in textile products, and the limited study was only performed to reuse/recycle the wastes in any country.

Therefore, much research was going on effective utilization of textile fiber wastes and or other solid wastes for further use in the same textile industry application or some other applications like agriculture or construction applications. It was also pointed out that the reuse of textile wastes could also hamper the production of raw textile materials and hence automatically reduction in the production of wastes. However, specific policies were implemented to reuse discarded textiles, i.e. around 20% and generated energy from there [310]. However, still, researchers are working on the effective utilization of wastes all over the world. Guyer et al. [311] discussed the waste management technique, reuse and recycle of textile wastes were one of the major factor as well as a challenging job in all most all the developing countries. It was observed that during cleaning and bleaching, the generated reactive dyes after treatment through advanced oxidation processes was investigated. The study concluded that during pad washing, nearly 100% water was recycled so that the fresh water consumption rate was reduced, which ultimately save fresh water purchase cost along with energy saving. Similarly, Silva et al. [312] pointed out that during different chemical and electrochemical advanced oxidation processes, much wastewater was generated that transferred into the environment. The same wastewater was reused again in textile industries after going through minor processing and then used for bleaching, scouring and dye processing. Based on the content of the review literature, the following hypothesis is proposed (Figure 3.2).

Hypothesis **H7:** Textile reuse and recycling in the textile industry is positively related to environment performance

3.4.8. Improvement of sustainability-related performance

Textile sectors are one of the major industries Worldwide for the production of textile products. The textile sectors also improve country economic condition as well as create a relationship between countries. However, during the manufacturing of textile products, large huge quantities of textile solid wastes are generated, which creates pollution in the localized area as well as being harmful to the human environment. Therefore, the sustainable textile sector needs to be developed to improve environmental quality and also environment-friendly by installing pollution-control technology as the effluents and wastewater are considered to be the most common pollutant. Hence, an application of green chemistry and clean technology leads to the development of environmentally friendly manufacturing system [313]. Gardas et al. [314] discussed three-dimensional sustainability such as economic, environment, and social that eliminated the barriers in the textile and apparel. Then it was identified that there exist nearly 14 challenges for sustainable development of textile and apparel sector by using decision making trial and proposed that poor infrastructure facility and lack of government policies were the most significant barriers.

Indian textile and clothing industry nowadays follows sustainability criteria through a supply chain that is mainly a combination of customer, manufacturers, and suppliers. The sustainability criteria were categorized into six numbers, and a sample size of 63 suppliers was considered, where the suppliers were of three groups, namely good, moderate, and poor performance. Finally, the grey approach was applied to analyze all the potential criteria's and reported the important criteria such as pollution, unfair competition, and employing child labors [316]. Nimkar [315] reported that the innovation in chemistry was highly required to achieve zero waste discharge by 2020 because, with the increase in global population, the chemical products all over the world also increase rapidly. They identified more than 8000 chemicals nominated under the supply chain group and these chemicals created huge chemical wastes, and hence, sustainability chemistry was the major solution for innovation in the present day industry success.

Nowadays, a huge number of approaches and methods are used such as life cycle assessment, life cycle costing as well as social life cycle assessment to obtain better products. Textile sectors by seeing the environment condition and harmful effect on human health, used a different methodology for sustainability performance. The main focus of the textile industries was to reduce the waste products and improve in three different dimensions such as economic, social and environment respectively by adopting multi-criteria decision making optimization technique (TOPSIS technique) [317]. Sawaf and Karaca [318] discussed the sustainability of wastewater treatment technology from textile industries in Turkey to obtain better performance in terms of economic technology, social and environment. To optimize the system parameters, they used the analytical hierarchy process (multi-attribute decision-making method) by incorporating sustainability criteria as well as their relevant indicators and observed that chemical treatment technology show the lowest sustainable alternative for textile sectors. Based on the content of the review literature, the following hypothesis is proposed (Figure 3.2).

Hypothesis **H8:** Improvement of sustainability-related performance in the textile industry is positively related to technology performance

3.4.9. Economic performance

Dutch textile industry discussed on the circular economy as well as institutional analysis for the arrangement of the organization in two different ways by developing a comprehensive conceptual framework. This may be because of adopting the circular economy creates new organization forms and inter-firm collaboration that is enhancing the sustainability of new institutions. However, later on, this circular economy concept after going through clear formulation as well as existing theories, this principle was lacking to establish a standard textile industry. Hence, after that introduced Status Quo arrangements and Product as Service arrangements to provide modified optimized technology, better infrastructure, circular relations and providing products subjected to the implementation of new approaches to the ownership of materials [318]. Fischer and Pascucci [319] discussed on low tech industries not only support the growth of economics and GDP in the countries but also simultaneously create the strong ground for improvement of technology as well as progress for innovation in subsequent development in the same research area. Hence, various laws and regulations were implemented by the Lithuanian industry in the state levels and observed that these industries loss their stability later on due to their rivals competitiveness. Brasil et al. [320] proposed a resource-based theory that mainly depends on three different sectors such as process, product and organizational and observed that after going through different textile industries performance data the business performance affected the product and organizational eco-innovations. This process automatically improves the technology of the textile sectors and simultaneously improved the performance of the textile industries.

Yin et al. [322] discussed two different major factors, such as the economy and environment as the most significant desirable parameters to improve the quality of any manufacturing industries. Pollution transfer and diffusion of wastes integrate for up gradation of economic development and then identify the series of wastes generated from industries by putting the pollution intensity index in manufacturing sectors. China implemented such index from 1997 to 2007 and proposed nearly eight sectors were under polluting industries out of which seventh industries were mining, food, textile, tobacco processing, and garments, etc. This study mainly focused on the identification of various gaps between the two countries, such as China and the US textile industry. The major key identification was an improvement of energy efficiency of chemical fiber industry and identified a few more factors that influenced the energy efficiency in China and compared with national-level results. Therefore, the key influencing factors that are required for improving the energy efficiency were technology, energy, and economic structure and industrial scale.

Martínez [253] focused on energy efficiency and energy use for the development of German and Colombian textile sectors to achieve sustainable development. In textile manufacturing industry, the implementation of energy consumption that directly improves the production level has a direct relationship between the output and energy use. This indicates that the development of technology, energy efficiency related policies, and mainly the implementation of management strategies improve the energy efficiency in the textile manufacturing industry. Whereas, Luthra and Mangla [321] discussed the implementation of Industry 4.0 such as product design, produced, delivery, and discarded to improve the business system. This study mainly focused on Indian manufacturing industries keeping in view for controlling the pollution, protecting the environment, and process safety for supply chain sustainability. However, adoption of Industry 4.0 was a challenging task for implementation because this concept is passing through a lot of analytical procedures. This technique not only improves the technological aspects but also improve other factors such as social and legal issues, strategic challenges, and ethical issues also.

Zhou et al. [323] discussed the reduction of freshwater use in textile dyeing industries by implementing the Genetic algorithm optimization technique. After going through various case studies, it was concluded that nearly 21% of fresh water consumption was reduced as compared with conventional processing techniques.

Nowadays, ecological footprint analysis was one of the crucial demands for societal benefit and able to demonstrate new potential applications on the biosphere. The main insight behind the present approach is the development of new tools which are useful to calculate the environmental impact as well as the environmental performance of various types of manufacturing processes [324]. Based on the content of the review literature, the following hypothesis is proposed (Figure 3.2).

Hypothesis **H9:** Economic performance in the textile industry is positively related to firm performance

3.4.10. Environmental impact

Sustainable environmental impact on the textile sector is one of the significant concerns nowadays for sustainable production improvement. Hence, sustainable production is required to improve consumption efficiency and simultaneously consumption pattern. The reduction in resource consumption need is required for improvement in technology as well as eco-efficiency support system because today most of the textile manufacturing industries are facing problems on climate change related problem, pollution increase in the environment, degradation of eco-system and raw materials exhaustion. Busi et al. [347] discussed the implementation of nanotechnology for textile industries to improve the technological potential and observed that this new concept develop technology in textile sectors. This improves the process performance in terms of energy and consumption of resources so-called self-cleaning textiles. Nanocrystalline TiO_2 photocatalytic layer was deposited on the surface of the new textile, which could easily destroy organic materials in the presence of solar irradiation. Therefore, automatically the maintenance cost of the textile products, use of the chemical is reduced and also a reduction in the uses of water for cleaning of textile products. Fan et al. [325] reported about China's national economy improvement by implementing green economy, which develops the economy in global scale because environmental protection industries in recent days are considered to be an emerging industry for the present economic condition as well as for future enhancement of economic strategy. This strategy subsequently provides a valuable model to the government agencies to implement a sound policy for improvement of environmental impact and economic condition.

Similarly, in Italy also introduced sustainability strategies successfully in textile sectors due to the increase in the number of textile industries. They also introduced a new decision-making process for monitoring management and environment system through which they could quickly identify the activity and improvement of mechanical performance. They finally controlled environmental pollution, cost saving, and also explored the sustainable business strategy [327]. In the same line, Jiang et al. [328] discussed the improvement of environmental efficiency in China's Jiangsu province and collected nearly 137 textile firms data. The data mostly covers the following major factors such as energy efficiency, output efficiency, wastewater and gas, labor, energy input, wastewater discharge, and emission of undesirable output. Finally, it was concluded that environment efficiency shows major impact on output efficiency, but the reverse had no impact.

Similarly, Shiwanthi et al. [329] reported the role of textile industry for the improvement of economic condition in Sri Lankan, as Sri Lankan was the fifth most significant contributor to CO_2 emission and major energy consumer in the world. With the increase in popularity of the production process of textile products in Sri Lanka, they adopted environmental production processes and followed sustainability as a tool for marketing. It was concluded that each company subsequently implemented the sustainability policy in their industries and obtained an eco-friendly environment that improved the revenue and eco-efficiency also.

However, Lo et al. [330] discussed the environmental management systems for the growth of financial performance in both fashion and textile sectors. Therefore, by the adoption of the environmental management system, the firm operational performance and profitability significantly improved, because profitability improvement was directly linked with cost efficiency and return on sale as per ISO 14000 certification standard. In Bangladesh textile sector controls entire country economic condition due to a large number of textile industries. This sector exports nearly 28 billion USD per annum, which nearly covers the country's 82% export earnings. In Bangladesh, the common export materials were ready-made garments that generally produce large quantities of wastewater, create environmental pollution, and discharging a large number of waste gases as well. That creates many health issues due to these waste effluents subsequently discharged into the river water. Hence, the lack of technology affects the environment to a large extent and other related issues [331]. Miller et al. [332] discussed the construction materials growing with the increasing demand impacting the environment with their production. The primary material was bio-based composites having a longer life, better mechanical properties, and creep deformation and one of the best alternatives than conventional materials. Textile reinforced bio-based composites were better environmental friendly and better life as far as a construction material was concerned. Again, the European Union main focus was waste prevention, eco-design, reuse and recycling of materials that depend on the circular economy. They estimated that nearly 17% of textile product gains second life and reuse of textile products also show higher benefits [326]. Muthukumarana et al. [333] discussed the environmental impacts in Sri Lanka for creating a sustainable industry that could provide a competitive and strategic advantage in the global market. However, it was observed that due to the lack of limited data available and no specific analysis was done about textile industries environmental concern. Therefore, life cycle analysis was made to quantify the amount of energy used, energy sources, transportation and production rate, etc. for garments products. Based on the content of the review literature, the following hypothesis is proposed (Figure 3.2).

Hypothesis **H10:** Environmental impact is positively related to firm performance

3.4.11. Operational performance

Textile industries in the US after the 1990s showed dramatic changes in the manufacturing of textile products in the global market because trade liberalization and clothing industries were opened in the US textiles market. It was observed that no doubt textile tread was increased, but the domestic manufacturing output in the US steadily decreased. Hence, most of the clothing industries slowly moved to other low salary countries. After the North American Free Trade Agreement, most of the textile industries were able to produce products in partnership with other countries. Due to which, the US textile sector developed had faster growth in collaboration with other developing countries [334]. Brazil textile sectors were more concern about environmental safety and simultaneously improved competitiveness in the international market. They always used a well-defined structured procedure to reduce their other costs and expenses.

Lucato et al. [335] investigated through the survey the environmental performance correlated with eco-efficiency level along with the financial performance of textile manufacturing industries by considering both small scale and medium scale industries. They also suggested that due to a limitation in surveying these two parameters, i.e., both environment and financial performance correlation the achievement of financial performance was challenging to achieve. There was huge literature available on the correlation between a firm's inventory and financial performance, but limited research was conducted on operational management and operations managers. This study was focused on the supply-demand mismatch in the firm's safety performance textile and fashion manufacturing sectors. Hence, by adopting this concept, the complex operating performance and environment become safe along with significant improvement shown in health, safety management, and operational management [337].

Aziz et al. [338] reported that wastewater treatment was one of the tedious, challenging tasks in the textile industry and the methods adopted till date were not capable of doing successful treatment. This study explained two inorganic coagulants such as $TiCl_4$ and $ZrCl_4$ having high cationic charges used for the treatment of textile wastewater to remove ammonia, suspended solids, and chemical oxygen demand. Textile industries mainly used a high quantity of fresh water and produced huge quantity of wastewater that is finally transferred to river water, and in few cases, the wastewater was evaporated to the environment generally in textile finishing industries. However, a limited analysis was done to date on woolen textile production with the reduction of water consumption, pollutant load, and wastewater generation by using appropriate technology. There were nearly 82 techniques performed and out of which nine techniques were used for woolen textile production successfully. Finally, they reported that nearly 69% water consumption, wastewater amount nearly 75%, and wastewater chemical load by 63% were reduced by minimization technique [339].

Information management was also a highly important technique to achieve better process management in the present competitive market and also probably impact on the operational performance. It was also observed that after studying more than 200 manufacturing firms in Australia, the interrelationship between internal and external management information correlated with the internal and external process management successfully [340]. Kovach et al. [341] observed mainly two factors to improve firm performance in order to achieve the firm's dynamic environment. They also collected nearly 3857 publicly traded firms' data about these factors such as operational scope and operational slack that improved unpredictable environment performance as well as unpredictable environment respectively that ultimately improved firm performance. Kenyon et al. [336] explained that initiations of supply chain technique improved the performance of manufacturing firms and observed that most of the practitioners as well as academics combined shown best practice. They also reported that supply chain and quality management could help better operational performance when outsourcing production that ultimately improved the new technology and on-time delivery.

However, Sahinkaya et al. [348] discussed process performance by using dynamic membrane bioreactor for the treatment of wastewater in textile industries. The use of dynamic membrane bioreactor in the dynamic layer could easily detect the soluble organics together with the identification of proteins and polysaccharides, respectively through FTIR analysis. As per literature, it was observed that supply chain integration mainly biased to obtain a positive impact on operational performance. The purpose of this discussion was to create a relationship between customer integration as well as operational performance that allows both buyers and suppliers to develop standard forecasting. Similarly, Cámara et al. [342] discussed specific types of supply chain integration and cloud technology as well as a physical flow that improve operational performance. Based on the content of the review literature, the following hypothesis is proposed (Figure 3.2).

Hypothesis **H11:** Operational performance in the textile industry is positively related to firm performance

Chapter summary

The conceptual framework produces a sustainable benchmark to the society; the manufacturing industry as well as policymakers, specifically textile industries along with other allied organizations.

The next chapter describes the Analysis of influencing factors on the sustainability of textile wastewater in India.

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Chapter-4

Analysis of influencing factors on the sustainability of textile wastewater in India: A structural equation approach

4.0. Introduction

In the present study, based on the available literature, it was found that the various textile industries mainly focused on multiple factors and performance measures. Moreover, a conceptual framework for sustainable textile wastewater management concept in the textile industry was developed, and further, the proposed model was examined based on the effect of economic performance, environmental impact and operational performance in textile sectors.

4.1. Literature review

The textile industry is one of the largest textile processing industries in Asia as well as in the world, mainly textile manufacturing and export companies. These industries not only help to improve Indian economy but also one of the most significant services provider (35 million people) and expected to generate 12 million new job opportunity shortly next to agriculture sectors [349]. Textile industries are simultaneously making a massive quantity of textile wastewater effluent, which creates a significant problem regarding chemical water as well as environmental pollution at the time of dying and finishing of textile fibers. There is no doubt that nowadays, most advanced techniques adopted for the treatment of textile fibers and the reuse of effluent water in textile industries [209]. The textile wastewater effluent contains multiple numbers of dyes and chemical such as basic red 46, reactive blue 198, yellow GR, Orange 2R and 3R, Na_2Co_3, NaCl, $NaC_6H_7O_6$ and a large number of solid wastes (Cr, As, Cu and Zn) [350]. These chemicals are available in different percentages in different effluent water based on the textile industries dye quantity and quality uses for different types of fibers. Therefore, the treatment process also varies from industry to industry such as ozonation [351], electrochemical oxidation [352], fungal degradation [353], screening, sedimentation, homogenization, neutralization, chemical flocculation, activated sludge, aerobic and anaerobic treatment, membrane technologies, adsorption, oxidation techniques and thermal evaporation [354].

In recent years, based upon the problems in various textile industries starting from dye printing to manufacturing of the final textile product, in each step lot of chemical wastes are generated. Hence, in every country, the government is implementing various policies to reduce environmental pollution and simultaneously to improve productivity [355]. Therefore, every textile industry is trying to adopt the sustainability of textile wastewater management principle for the survival of the textile sector. Moreover, these industries create environmental problems and also affect human health seriously. Pattnaik et al. [244] successfully reviewed last twenty years research papers including books on the sustainability of textile sectors wastewater management. Sustainability in Textile wastewater management mainly links to the following main dimensions such as Economic performance, Environmental impact, and Operational performance, respectively as per present desirable. However, researchers were also focusing on the following four dimensions,i.e., environment, social, economic, and political system [356,357].

Yuan and Tian [358] discussed various structural-equation-modeling (SEM) methodology to understand the interrelationship between their observed indicators and among latent attributes. They also clearly pointed out various methods limitations part as well as advantages by implementing SEM methodology. Neto et al. [359] discussed the private education system for higher study, specifically industrial engineering student by using structural equation modeling and suggested that teacher involvement results in major satisfaction to students. Ajayi and Oyedele [360] reported a reduction of construction waste and simultaneously implemented a lot of design factor using SEM in construction projects. It was suggested that these two major factors purely depend on the reduction of construction waste, i.e., standard materials size as well as the modern method of construction. Therefore, most of the researchers successfully implemented a lot of statistical techniques for factor analysis in their survey data and then developed various dimensional for structural model validation.

4.2. Methodology

After a comprehensive literature review in our previous publication by the same group, Pattnaik et al. [244], a series of the questionnaire prepared. The major points were identified to complete the survey procedure such as labor input in the textile industry, Policy implications, Dyes and additives, Wastewater treatment and disposal, Energy consumption and carbon dioxide emissions, Textile industry productivity, Textile reuse, and recycling, Improvement of sustainability-related performance, and performance measures were Economic performance, Environmental impact and Operational performance respectively (Table 4.1). This research work mainly deals with the detail of site selection for the survey, data collection methodology, analysis of the survey data, normality and reliability analysis, development of structural-equation-modeling, confirmatory factor analysis and finally validation of results for sustainability of textile wastewater management.

Table 4.1. Factors Definition

Explained or dependent factors ➢ Economic Performance ➢ Environmental Impact ➢ Operational Performance	➢ Applying the results of cost, quality improvement, and related technology controlled in the process of TWWM. ➢ The textile industry is considered as one of the most polluting industries in the world, and hence, the reduction of pollution in the environment is highly required. ➢ Operational performance overall depends on the utilization of advanced technology and economic performance also.
Explanatory factors ➢ Labor input in the textile industry ➢ Policy Implication ➢ Textile reuse and recycle ➢ Dyes and additives ➢ Wastewater treatment and disposal ➢ Energy consumption and carbon dioxide emission ➢ Textile industry	➢ It measures the effectiveness and efficiency of an organization in generating output with the resources available. ➢ Policy implementation in developing countries called carbon tariffs policy for better performance in the international market. ➢ Effective utilization of textile fiber wastes and or other solid wastes for further use in same textile or agriculture or construction applications. ➢ Dye and additives are the major ingredients to improve the performance of the textile fibers, and

productivity ➢ Improvement of sustainable related performance	because of these dyes, the final cloth image changes drastically as per present customer desire. ➢ Effective utilization of water and reuse of wastewater for different applications again and again to control the environment. ➢ Most of the textile industries generate much heat during treatment as well as other sources of heat generated through air conditioner and compressors. ➢ Improvement of production rate in textile sectors. ➢ the sustainable textile sector needs to be developed environment-friendly by installing pollution-control technology
Mediator factors ➢ Sustainability of textile wastewater management	➢ Sustainable textile wastewater management, that depends on economic performance, environmental impact, and operational performance

4.2.1. Site selection

The textile fiber manufacturing and processing sectors are one of the oldest as well as largest organized sectors in India. There are over 7000 large-scale textile industries and small-scale industries concentrated mainly in Rajasthan, Gujarat, Maharashtra, Odisha, and Tamil Nadu states. In the rural part of India, several textile industries are nowadays improving the quality of products and increasing their demand equality in the other part of India as well as in the international market. However, the discharge of solid wastes and textile wastewater effluent are not controlled till date due to the stringent law formed in most of the developing countries. Hence, these wastes are transferred through drains to the nearby rivers, which ultimately pollute the environment and increase water pollution. Therefore, proper disposal practices are highly required to improve the performance of textile industries. As far as literature was concerned, most of the developing countries are focussing on the textile industries, conducting many awareness programs and also finding alternative utilization of these textile wastes for manufacturing of low-grade-tiles, ceramic bricks by replacing cement and also agriculture purposes.

4.2.2. Data collection

The main information was collected purely based on a primary date through survey instrument from all over India, in different textile Industries. The authors developed the questionnaire based on available literature on textile wastewater management as well as consulted different textile industry experts (**Annexure A & B**). The following major factors were selected for sustainable wastewater management, as shown in Table 4.2, along with their respective sub-criteria. These eleven factors and sub-criteria will be prepared for the further model and hypothesis development, and model validation, respectively. The study initially selected 352 textile Industries from all the parts of India and nearly 300 textile industries responses were received. In the end, 264 textile industries questionnaire were finalized for validation as well as for further structural analysis. All the analyses were performed using the IBM Statistical Package for Social Sciences for MAC (SPSS, v22) and AMOS (v21).

Table 4.2. List of factors and sub-factors

Dimensions	Dimension Code	Factors	Factors Code
Labor input in the textile industry	LITI	Increase in employee wages	LITI-1
		Difficulty in recruiting general staff	LITI-2
		Low rate of worker retention	LITI-3
		Difficulty in recruiting engineer staff	LITI-4
Policy implications	PI	Unstable political and social conditions	PI-1
		Underdeveloped infrastructure (electric power, transportation, communications, etc.)	PI-2
		Unclear policy management by the local government	PI-3
		Complicated tax procedures	PI-4
Dyes and additives	DA	Basic dyes, Mordant dyes and Acid Dyes (Silk, Wool, Nylon (Ionic bond))	DA-1
		Direct dyes and Disperse dyes (Cotton, Polyester, Acetate (Ionic bond))	DA-2
		Vat dyes and Sulphur dyes (Cotton, Cellulose (Dye precipitated in the fiber))	DA-3
		Azoic dyes and Reactive dyes (Cotton, Cellulose (Covalent binding))	DA-4
Wastewater treatment and disposal	RTD	Landfill	RTD-1
		Agricultural use	RTD-2
		Recovery	RTD-3
		Building and construction materials	RTD-4
Energy consumption and carbon	ECCDE	Implementation of a certified Energy-Management-System according to ISO 50.001 as requested by public bodies or customers	ECCDE-1

dioxide emissions		The energy footprint of a production order/article regarding the energy consumption in any company	ECCDE-2
		Post calculation: Comparison of actual and planned costs in order to identify significant deviations	ECCDE-3
		Establishing Services to support Carbon-Emissions Trading (forecast, sourcing)	ECCDE-4
Textile industry productivity	TIP	Regulation influenced technology transfer and R&D activities of your firm	TIP-1
		Has the flow rate of productivity change	TIP-2
		Hasyouadopt to improve productivity?	TIP-3
		Have you plan to increase the degree of automation of your production	TIP-4
Textile reuse and recycling	TRR	Reuse (Run your own store)	TRR-1
		Reuse (Sell to non-profits or other businesses)	TRR-2
		Reuse (Sell to a broker)	TRR-3
		Recycling	TRR-4
Improvement of sustainability -related performance	ISRP	Sludge disposal efficiency	ISRP-1
		The efficiency of sludge treatment	ISRP-2
		Weighted average Reagent consumptions	ISRP-3
		Sustainable Performance Measurement for Textile Wastewater Treatment Plants	ISRP-4
Economic performance	EP	Reduction in costs through improved efficiency of production and sales	EP-1
		Expand the range of low price products/services	EP-2
		No measures have been taken	EP-3
		Increased efficiency through management integration within the group	EP-4
Environmental impact	EI	Stricter environmental regulations	EI-1
		In your view, has air pollution ever affected your health	EI-2
		Apart from effects on people's health, are you aware of any other effects of air pollution	EI-3
		Jobs today are more important than protecting the environment for the future	EI-4
Operational performance	OP	Brand identity is strong and established	OP-1
		Goodwill is already earned due to old customers in the market	OP-2
		Old customer relationship and retaining them successfully	OP-3
		Quality of the fabric is up to the mark	OP-4

4.2.3. Data analysis

The exploratory factor analysis was generally performed by using the principal component analysis technique (PCA) through SPSS statistical analysis software tool to evaluate the component scores and loading (eigenvalues of at least one), Varimax rotation method (Kaiser normalization) [361], reliability statistic, Kaiser-Meyer-Olkin (KMO)Measure of Sampling Adequacy, Bartlett's Test of Sphericity, degree-of-freedom (DoF) and degree of significance. In the end, bi-variate correlation analysis (BCA) was also performed to observe the inter-correlation of factors. After confirming the above analysis, the next step was to prove the proposed hypothetical model and then to fit the model to a structural equation modeling (SEM) analysis by AMOS V-22.0. The proposed model verified by examining the goodness-of-fit statistics indices: a ratio of Chi-square to a DoF, a goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), Normed-Fit-Index (NFI), comparative-fit-index (CFI) and root mean square error of approximation (RMSEA).

4.3. Exploratory factor analysis (EFA)

The principal component analysis (PCA) was implemented in the present collected data to find out the number of factors required for sustainable textile wastewater management and performance measures. However, before applying PCA analysis, KMO Test (value higher than 0.7) and Barlett's test (BT) were calculated to understand the homogeneity of the data for sampling adequacy [362]. The KMO and BT results were 0.784 and 6051.79 respectively, with the significance of 0.000, which justify the desired values as per available literature. Similarly, Initial Eigenvalues, Extraction Sums-of-Squared loadings, and Rotation Sums-of-Squared loadings were calculated with 44 items, which included eight factors and three performance measures, as shown in Table 4.3. The total variance was 67.106 percentages with more than one eigenvalues. In the present case, the eight factors are 1. Labor input in the textile industry, 2. Policy implications, 3.Dyes, and additives, 4.Wastewater treatment and disposal, 5.Energy consumption and carbon dioxide emissions, 6.Textile industry productivity, 7.Textile reuse and recycling, 8. Improvement of sustainability-related performance and the remaining three are performance measures, i.e., 1. Economic performance, 2.Environmental impact and 3.Operational performance, respectively in order to achieve sustainable wastewater measurement respectively.

Table 4.3. Component scores and loadings

Total Variance Explained

Component	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.312	16.619	16.619	7.312	16.619	16.619	3.728	8.473	8.473
2	4.091	9.298	25.916	4.091	9.298	25.916	3.120	7.090	15.563
3	3.091	7.025	32.942	3.091	7.025	32.942	2.841	6.457	22.020
4	2.776	6.308	39.250	2.776	6.308	39.250	2.798	6.359	28.379
5	2.475	5.624	44.874	2.475	5.624	44.874	2.666	6.058	34.437
6	2.044	4.644	49.519	2.044	4.644	49.519	2.649	6.019	40.457
7	1.859	4.226	53.744	1.859	4.226	53.744	2.562	5.823	46.279
8	1.651	3.751	57.495	1.651	3.751	57.495	2.506	5.696	51.976
9	1.613	3.667	61.162	1.613	3.667	61.162	2.291	5.207	57.183
10	1.398	3.177	64.339	1.398	3.177	64.339	2.258	5.132	62.315
11	1.217	2.766	67.106	1.217	2.766	67.106	2.108	4.791	67.106

Extraction Method: Principal Component Analysis.

* 1-8 components indicate the factors and 9-11components indicates the performance measures

4.4. Normality Test

In this study, the correlational analysis was also performed to test the normality of the proposed data collected through a survey for the sustainability of textile wastewater management and this test was also performed to identify the shape of its distribution. Therefore, based on the analysis of the skewness and kurtosis measuring values were within the range of +/-1.5, as reported earlier [362]. From Table 4.4, it was indicated that all the values of skewness and kurtosis are within the range of acceptable limit, and this would indicate whether the data normally distributed or not. Therefore, based on the test, the data was determined as normally distributed, since the results of skewness and kurtosis were in the range of +/-1.5 for each factor.

4.5. Tests for reliability and validity of the collected data

Internal consistency of the multiple-item was also calculated for the reliability of the items by using Cronbach's alpha [363] and it was observed that for all most all the factors obtained results were within the acceptable limit (equal to or higher than 0.70) as shown in Table 4.4 except for two-factor alpha values less than 0.7. However, Cronbach's alpha was higher than 0.6 preferred to reveal internal consistency. Therefore, wastewater treatment and disposal (Cronbach's alpha = 0.672) and Economic performance (Cronbach's alpha = 0.640) were considered in this study, for analysis and the construct had satisfactory reliabilities.

Table 4.4. Factors and its scale reliabilities

Dimension Code	Skewness Statistic	Skewness Std. Error	Kurtosis Statistic	Kurtosis Std. Error	Factor loading	Cronbach's α	KMO
LITI	-.830	.150	-.362	.299	.753	0.729	0.717
	-.238	.150	-.397	.299	.720		
	-.976	.150	.842	.299	.757		
	-.188	.150	-.539	.299	.571		
PI	.131	.150	-.661	.299	.853	0.795	0.747
	.113	.150	.559	.299	.735		
	.092	.150	-.210	.299	.824		
	.384	.150	-.605	.299	.600		
DA	-.823	.150	-.310	.299	.760	0.877	0.738
	-.331	.150	.026	.299	.686		
	-.584	.150	-.251	.299	.840		
	-.212	.150	-.174	.299	.891		
RTD	.747	.150	.028	.299	.700	0.682	0.680
	-.168	.150	.211	.299	.758		
	.191	.150	-1.331	.299	.563		
	.093	.150	-.484	.299	.687		
ECCDE	-.009	.150	-.472	.299	.778	0.798	0.708
	-.030	.150	-.193	.299	.787		
	.401	.150	-.307	.299	.781		
	.131	.150	-.358	.299	.682		
TIP	-.488	.150	1.026	.299	.651	0.759	0.750
	-.455	.150	-.701	.299	.564		
	-.454	.150	-.838	.299	.793		
	-.988	.150	-.056	.299	.819		
TRR	-.356	.150	-.850	.299	.871	0.960	0.847
	-.423	.150	-.654	.299	.917		
	-.518	.150	-.629	.299	.945		
	-.491	.150	-.645	.299	.941		
ISRP	.445	.150	.493	.299	.780	0.770	0.766
	-.026	.150	-.121	.299	.743		
	-.005	.150	-.679	.299	.735		
	.433	.150	-.743	.299	.699		
EP	-.546	.150	.173	.299	.653	0.640	0.652
	-1.046	.150	.083	.299	.583		
	-.043	.150	-.086	.299	.685		
	-.087	.150	-.266	.299	.632		
EI	-.148	.150	-1.485	.299	.685	0.811	0.789
	.058	.150	-.195	.299	.827		
	.265	.150	-.130	.299	.828		
	.237	.150	-.537	.299	.817		
OP	.217	.150	-.716	.299	.615	0.780	0.723
	.174	.150	-.220	.299	.742		
	-.049	.150	-.972	.299	.852		
	-.005	.150	-1.107	.299	.700		

After that validity of the constructs was derived for the following factors, because for each factor, there were four items, and these items were extracted from exhaustive literature [244]. Factor loading was also one of major analysis to estimate the correlation among different sub-criteria concerning their factors, and as per available literature, the factors with loading more than 0.4 were considered [364]. Comrey and Lee [364] elaborated that a factor with loading more than 0.71 was considered excellent, for loading 0.63 was considered very good, but factor loading within 0.55 was considered good. However, any factor with the loading of less than 0.45 was considered fair, but further analysis might be required to improve the factor loading.

Hence, by discussing the above criteria, the present rotated component matrix was within the acceptable limit, as shown in Table 4.4, and cross loading was not observed to remove any factor from this analysis. Again, another alternative was also computed to measure the sampling adequacy, i.e., Kaiser–Meyer–Olkin (KMO) which purely specifies how small the partial correlations were relative to the original correlations. However, smaller values of KMO demonstrate that other factors cannot explain the correlations between pairs of factors. The KMO should be more than 0.60 [361], but the values lie between closer to 0.80 or 0.90 suggest the inter-correlation matrix is almost ideal for factor analysis [365]. Table 4.4 shown the KMO values of all the eleven having more than 0.60 KMO values, and then the factors were ideal for factors analysis. Table 4.5 shows the bivariate correlations computed using available data sets through a survey for sustainable wastewater management in textile industries. A negative-correlation may cause an inverse relationship, but a positive-correlation shows these fractions may vary in the same direction.

Moreover, while a correlation coefficient of value, ±0.5 shows a healthy relationship between the two fractions and for a perfect correlation, the value is 1. Based on the bivariate correlations analysis by rotation method, a positive and significant correlation coefficient between Economic performance and the eight remaining factors was established, as shown in Table 4.5. In contrast, the negative and significant correlation coefficient was observed between these two performance measures (Environmental impact and Operational performance).

Table 4.5. Bivariate correlation analysis

Correlations

	LITI	PI	DA	WTD	ECCDE	TIP	TRR	ISRP	EP	EI	OP	Mean	Std. Deviation
LITI	1											4.19	.512
PI	.329**	1										4.03	.427
DA	.408**	.187**	1									3.97	.622
WTD	.244**	.260**	.326**	1								3.81	.491
ECCDE	.080	.092	.155*	.259**	1							3.81	.483
TIP	.234**	.128*	.371**	.182**	.173**	1						4.31	.444
TRR	.188**	.123*	.290**	.115	.103	.329**	1					4.39	.574
ISRP	.094	.158**	.161**	.151*	.313**	.194**	.072	1				3.60	.473
EP	.234**	-.005	.298**	.103	.108	.306**	.210**	.150*	1			4.12	.462
EI	-.022	.095	.102	.142*	.011	.058	-.037	.130*	.095	1		3.64	.596
OP	-.087	-.046	-.275**	.107	.161**	-.233*	-.208*	.183**	-.291*	-.040	1	3.74	.603

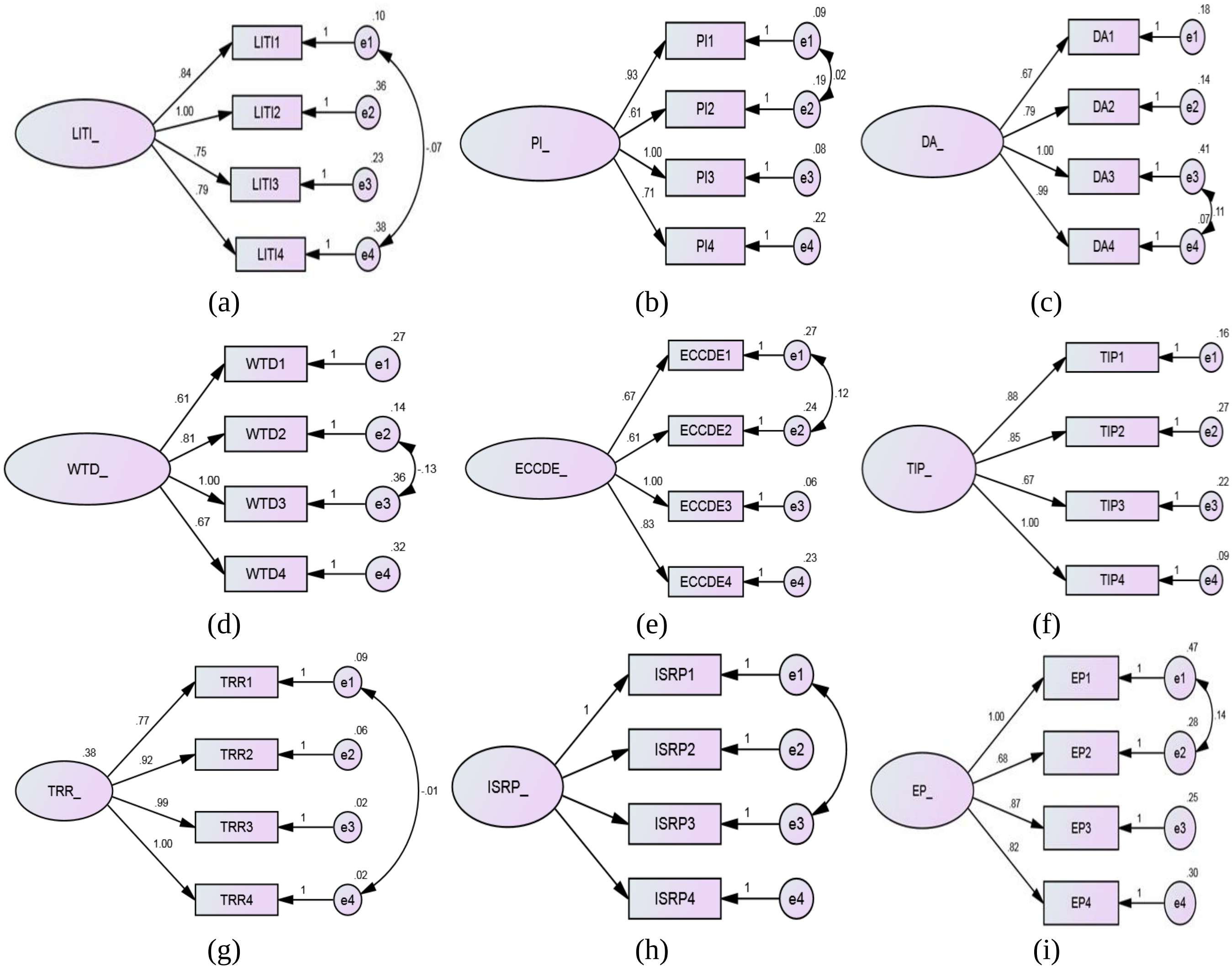
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

4.6. Structural equation modeling (SEM)

The labor input in the textile industry, policy implications, dyes and additives, wastewater treatment and disposal, energy consumption and carbon dioxide emissions, textile industry productivity, textile reuse and recycling, improvement of sustainability-related performance, economic performance, environmental impact and operational performance were built and validated by confirmatory factor analysis (CFA). In this study, two levels of analysis were included, i.e., one measurement model (which indicates how hypothetical constructs were measured regarding the observed factors) and other one structural model (which makes relationships among the constructs) [366]. The first step of this part of the analysis was to evaluate each factor and its sub-factor because at the end, finally integrated was developed to validate the proposed structural model and any amendments found during analysis to achieve the best-adjusted model the factor or their sub-criteria may be omitted further analysis. Figure 4.1 shows all the eleven factors,one-factor congeneric model. The rectangle indicates an observed item or factor, and the circle displays a latent construct [366].

4.6.1. First order confirmatory factor analysis

After individual factor validation, eight factors were used for first-order confirmatory factor analysis, and the remaining three factors were suggested for performance outcome to implement sustainable wastewater management principle in textile industries. After confirmatory factor analysis, the full latent variable model was studied. The result of the structural model with the recommended values of the fit indices for the satisfactory fit of a model to obtain data was shown in Table 4.6. The goodness-of-fit statistics were in the range of the recommended values, and no sub-criteria were deleted in CFA since all the proposed factors were statistically significant. Therefore, the structural model and measurement model were satisfactorily fit the data. The results suggested that the model met adequately with the data.



(j) (k)

Figure 4.1. One factor congeneric model of all the factors and sub-factors

Table 4.6. Measurement of model fit indices

	LITI	PI	DA	WTD	ECCDE	TIP	TRR	ISRP	Desired levels [357]
χ^2/df	2.932	4.616	4.714	1.317	3.807	1.826	1.850	2.305	0.02-4.80
GFI	0.994	0.991	0.991	0.998	0.993	0.993	0.997	0.996	0.75-0.99
AGFI	0.945	0.914	0.912	0.975	0.929	0.964	0.965	0.957	0.63-0.97
NFI	0.988	0.987	0.993	0.993	0.990	0.987	0.999	0.992	0.72-0.99
CFI	0.992	0.989	0.995	0.998	0.992	0.994	0.999	0.995	0.88-1.00
RMSEA	0.086	0.117	0.119	0.035	0.103	0.056	0.057	0.070	0.00-0.13

Table 4.7 presents the summary of confirmatory results of sustainable wastewater management (the eight factors) evaluated by using Analysis of Moment Structures (AMOS 22.0) as shown in Figure 4.2 and the values of Estimate (Standardized), Squared Multiple Correlations (R^2), Average-variance-extracted (AVE), Composite reliability (C.R), Average shared variance (ASV) and Maximum shared variance (MSV) respectively. As per the standard literature available for validation of the above criteria, the AVE should be either greater than or equal to 0.50 and CR should be greater than or equal to 0.60 (Bagozzi and Yi 1988) and Criteria for ensuring discriminant validity are MSV < AVE and ASV < AVE [362] and Squared Multiple Correlations was also within the range. Table 4.7 shows the Estimate (Standardized), standard error (SE), critical-ratio-for-regression weights (CR), and Squared Multiple Correlations. The squared multiple correlations (r^2) values were adequately higher with the ranging from 0.290 to 0.960. Hence, all the constructed eleven factors were a good fit due to the squared multiple correlations (r^2) values and confirmed that the factors were unidimensional.

Again, the critical ratio for regression weights (CR) value in the test statistics was higher than 1.96 with probability (p) < 0.05.

Table 4.7. Summary of Confirmatory Analysis (Reliability and validity for individual constructs)

Construct	Items	Estimate (Standardized)	Squared Multiple Correlations (R^2)	Average variance extracted (AVE)	Composite Reliability (C.R)	Average shared variance (ASV)	Maximum shared variance (MSV)
LITI	LITI1	.811	.316	0.496125	0.795611	0.2729	0.2304
	LITI2	.667	.413				
	LITI3	.643	.445				
	LITI4	.563	.657				
PI	PI1	.814	.326	0.576703	0.842718	0.1900	0.1369
	PI2	.538	.722				
	PI3	.850	.290				
	PI4	.571	.663				
DA	DA1	.721	.854	0.636919	0.87421	0.3086	0.2304
	DA2	.814	.514				
	DA3	.717	.663				
	DA4	.924	.519				
WTD	WTD1	.549	.305	0.463376	0.77357	0.2614	0.1369
	WTD2	.774	.467				
	WTD3	.684	.599				
	WTD4	.552	.301				
ECCDE	ECCDE1	.557	.457	0.574935	0.843568	0.2071	0.1369
	ECCDE2	.549	.830				
	ECCDE3	.911	.302				
	ECCDE4	.676	.310				
TIP	TIP1	.707	.697	0.510377	0.803175	0.2871	0.2025
	TIP2	.598	.303				
	TIP3	.551	.357				
	TIP4	.835	.500				
TRR	TRR1	.844	.960	0.844509	0.955952	0.1900	0.1296
	TRR2	.917	.946				
	TRR3	.972	.841				
	TRR4	.980	.713				
ISRP	ISRP1	.837	.328	0.547319	0.828442	0.2286	0.0961
	ISRP2	.661	.511				
	ISRP3	.715	.437				
	ISRP4	.573	.701				

Note: CR >average variance explained (AVE), AVE>0.5, CR >0.7, (Hair et al., 2006).
Criteria for ensuring discriminant validity are MSV <AVE and ASV <AVE (Hair et al.2006)

However, the composite reliability for all the factors was higher than the 0.7, but the average variances extracted for one factor was closer to 0.5, but the factor (WTD) average variance extracted was marginally lower. These results suggest that the internal consistencies of the constructs are satisfactory. In conclusion, it can be stated that all constructs are reliable.

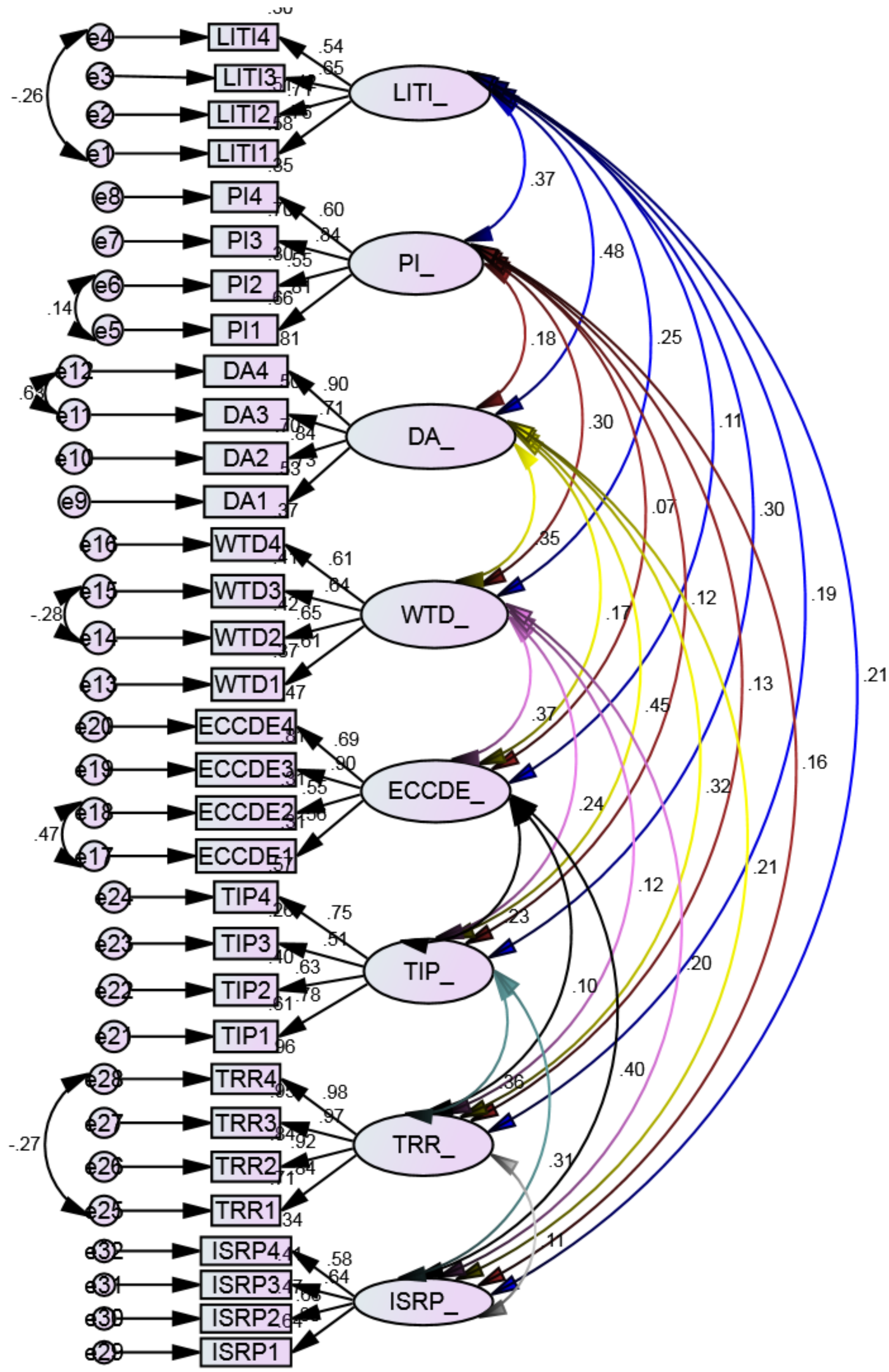


Figure 4.2. First-order CFA measurement model

4.6.2. Second-order structural model evaluation

The eight selected factors of sustainable wastewater management were found adequate goodness-of-fit indices achieved [362]. The second-order-model (Figure 4.3) evaluation, estimates the following criteria such as the goodness-of-fit index (GFI) as 0.843, within the recommended threshold of 0.75-0.99, AGFI is acceptable at 0.815, higher than the recommended minimum of 0.63-0.97, normed-fit-index (NFI) was 0.837, and the recommended range was 0.72-0.99, Comparative-fit-index (CFI) was 0.924, higher than the threshold range 0.88-1.00. The root means-square error of approximation (RMSEA) of 0.052 was adequate since it was between 0.00-0.13. The evaluation of the other index of the normed chi-square was established to be 0.5 thresholds with $\chi 2/df = 1.708$ as recommended by Schumacker and Lomax [367]. It was concluded that the overall assessment of the criteria for model fit was acceptable for the eight items using second-order confirmatory factor analysis in its validation (Table 4.8).

Table 4.8. Goodness of fit indices for the proposed model (Model Fit Indices for second order)

Goodness of fit indices	Structural model	Desired levels (Živkovi´c, et al. [356])
Chi-square / Degree of freedom (χ^2 /df)	1.708	0.02-4.80
Goodness of fit index (GFI)	0.843	0.75-0.99
Adjusted goodness of fit index (AGFI)	0.815	0.63-0.97
Normed Fit Index (NFI)	0.837	0.72-0.99
Comparative fit index (CFI)	0.924	0.88-1.00
Root mean square error of approximation(RMSEA)	0.052	0.00-0.13
Minimum chi-square (CMIN)		

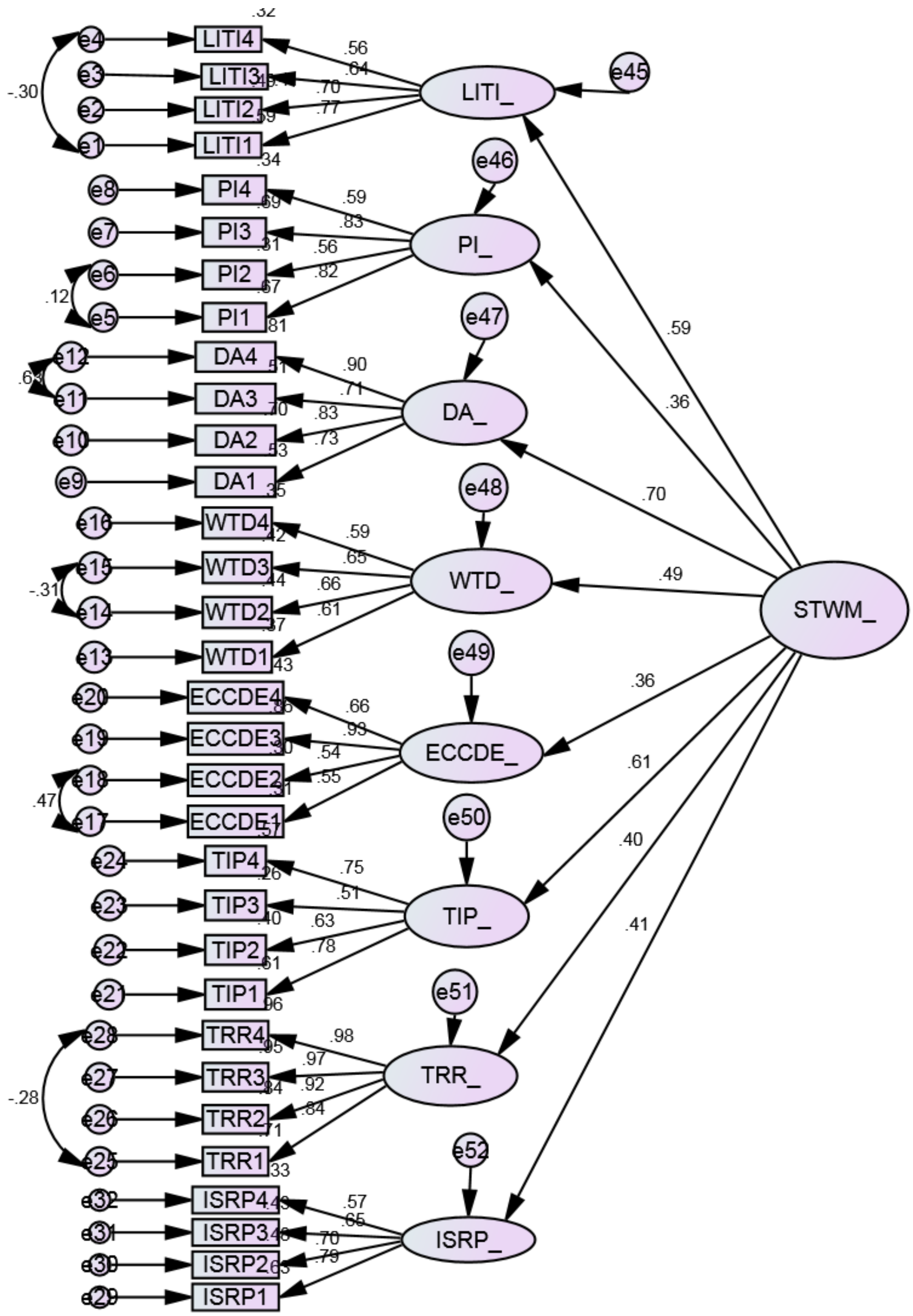


Figure 4.3. Second-order CFA measurement model

4.6.3. Multi-factor analysis

As seen in Table 4.9, all the parameters of the structural model conform to be recommended values, and the measurement model fits the data well (Figure 4.4). Most of the settings was within prescribed boundaries. The goodness-of-fit index (GFI) was 0.780, within the prescribed threshold of 0.75-0.99, AGFI was acceptable at 0.753, higher than the recommended minimum of 0.63-0.97, Normed-Fit-Index (NFI) is 0.752, and the recommended range was 0.72-0.99, comparative-fit-index (CFI) was 0.870, higher than the threshold range 0.88-1.00. The root means a square error of approximation (RMSEA) of 0.055 was adequate since it was between 0.00-0.13. Nevertheless, all the indicator sub-criteria loaded highly and signed on to their respective factors. Also, all the constructs of the structural model were positively correlated with each other.

Table 4.9. Goodness of fit indices for the proposed structural model (Model Fit Indices for multi-factor factor analysis)

Goodness of fit indices	Structural model	Desired levels (Živkovi´c, et al. [356])
Chi-square / Degree of freedom (χ^2 /df)	1.805	0.02-4.80
Goodness of fit index (GFI)	0.780	0.75-0.99
Adjusted goodness of fit index (AGFI)	0.753	0.63-0.97
Normed Fit Index (NFI)	0.752	0.72-0.99
Comparative fit index (CFI)	0.870	0.88-1.00
Root mean square error of approximation(RMSEA)	0.055	0.00-0.13
Minimum chi-square (CMIN)	1598.387	

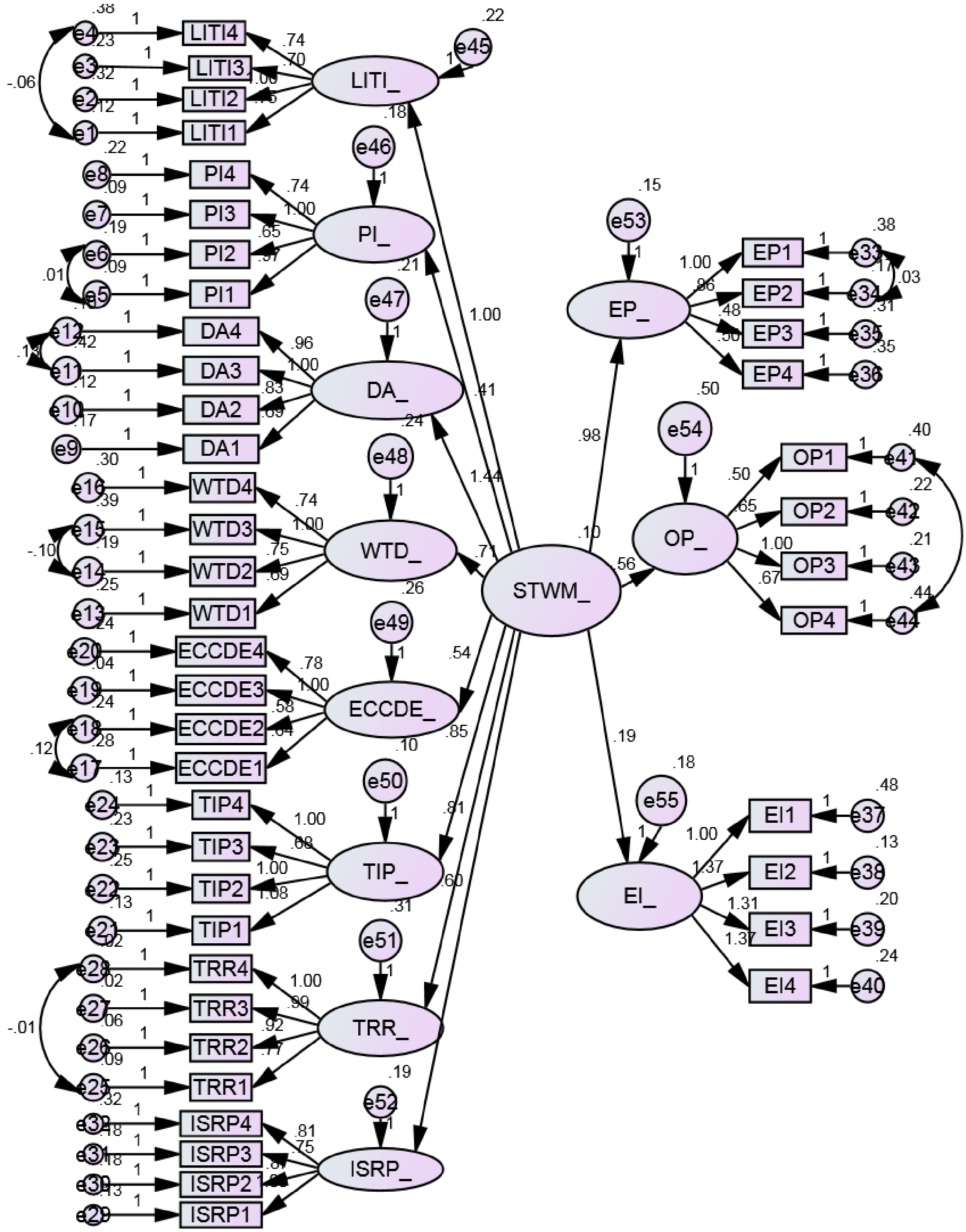


Figure 4.4. Multi-factor Structural Model

Chapter summary

1. The finding of the present research work was a successful construction of a structural model for the understanding of the sustainability of textile wastewater management in textile sectors. This study also helps the waste management researchers to identify the major factors along with their sub-factors during the manufacturing of textile products.
2. Therefore, based upon the present proposed structural model, the concept may be implemented in any textile industry in India for the sustainability of textile wastewater management principle as a case study analysis.

The next chapter describes the Sustainability of textile waste-water management by using an integrated fuzzy AHP-TOPSIS method: A case study

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Chapter-5

Sustainability of textile waste-water management by using integrated fuzzy AHP-TOPSIS method: A case study

5.0. Introduction

In the present research work, based on the available literature on the sustainability of textile waste-water management limited work has been reported on multi-criterion decision-making method. Hence, to make the textile sector more sustainable both the FAHP and FTOPSIS methods were implemented to ranking the proposed criterion based on their importance by FAHP in the first step. In the subsequent step, FTOPSIS technique is applied to prioritised the selected alternatives used in the textile manufacturing sectors to optimize the process parameters.

5.1. Evaluation methodology

The MCDM techniques are potential tools for evaluating complex problem due to their various dependent and independent variables for solving textile sectors manufacturing related problems. In this manuscript, the above eleven criterion have been proposed to improve from labour input to operational performance through the implementation of various policies (Table 5.1). Hence, such case relies on only survey report was not sufficient enough to bring sustainability in the textile sectors problem and therefore, for further improvement an implementation of multi-criterion decision-making method such as FAHP highly required for analysis. FAHP is mainly used to predict the weights of different criterion in order to improve the performance of the textile sectors as well as ranking the criterion in decreasing order. The methodology was consisting of the following three main steps as shown in Figure 5.1. In the first step, the alternatives identified which will be subsequently used in the evaluation of optimal sustainability of textile waste-water management approach. In the second step, the weight were assigned to each criterion by using FAHP technique as selected through literature, survey report and experts opinion respectively. In the last step, FTOPSIS method best alternate was determined by using. First, we briefly review the basic of fuzzy set theory before defining fuzzy AHP and fuzzy TOPSIS approaches.

Table 5.1 Description of the different performance defining attributes

Performance defining attributes	Description	Performance implications
Labor input in the textile industry	It is a measure of the effectiveness and efficiency of an organization in generating output with the resources available	C-1 lower-the-better
Policy implications	Policy implementation in developing countries called carbon tariffs policy for better performance in the international market and subsequently examined the policy from time to time	C-2 lower-the-better
Dyes and additives	Dye and additives are the major ingredients to improve the performance of the textile fibers, and because of these dyes, the final cloth image changes drastically as per present customer desire.	C-3 lower-the-better
Wastewater treatment and disposal	effective utilization of water and reuse of wastewater for different applications again and again to control the environment	C -4 lower-the-better
Energy consumption and carbon dioxide emissions	Energy conservation with emission reduction in textile industries because most of the textile industries generate much heat during treatment as well as other sources of heat generated through air conditioner and compressors	C-5 lower-the-better
Textile industry productivity	Improvement of production rate in textile sectors	C -6 Higher-the-better
Textile reuse and recycling	Effective utilization of textile fiber wastes and or other solid wastes for further use in same textile industry application or some other applications like agriculture or construction applications	C -7 Higher-the-better
Improvement of sustainability-related performance	the sustainable textile sector needs to be developed environment-friendly by installing pollution-control technology	C -8 Higher-the-better
Economic performance	Economic performance mainly defined the growth of textile products export and its contribution to total exports	C-9 lower-the-better
Environmental impact	The textile industry is considered as one of the most polluting industry in the world, and hence the reduction of pollution in the environment is highly needed.	C -10 Higher-the-better
Operational performance	Operational performance overall depends on the utilization of advanced technology and economic performance also.	C -11 Higher-the-better

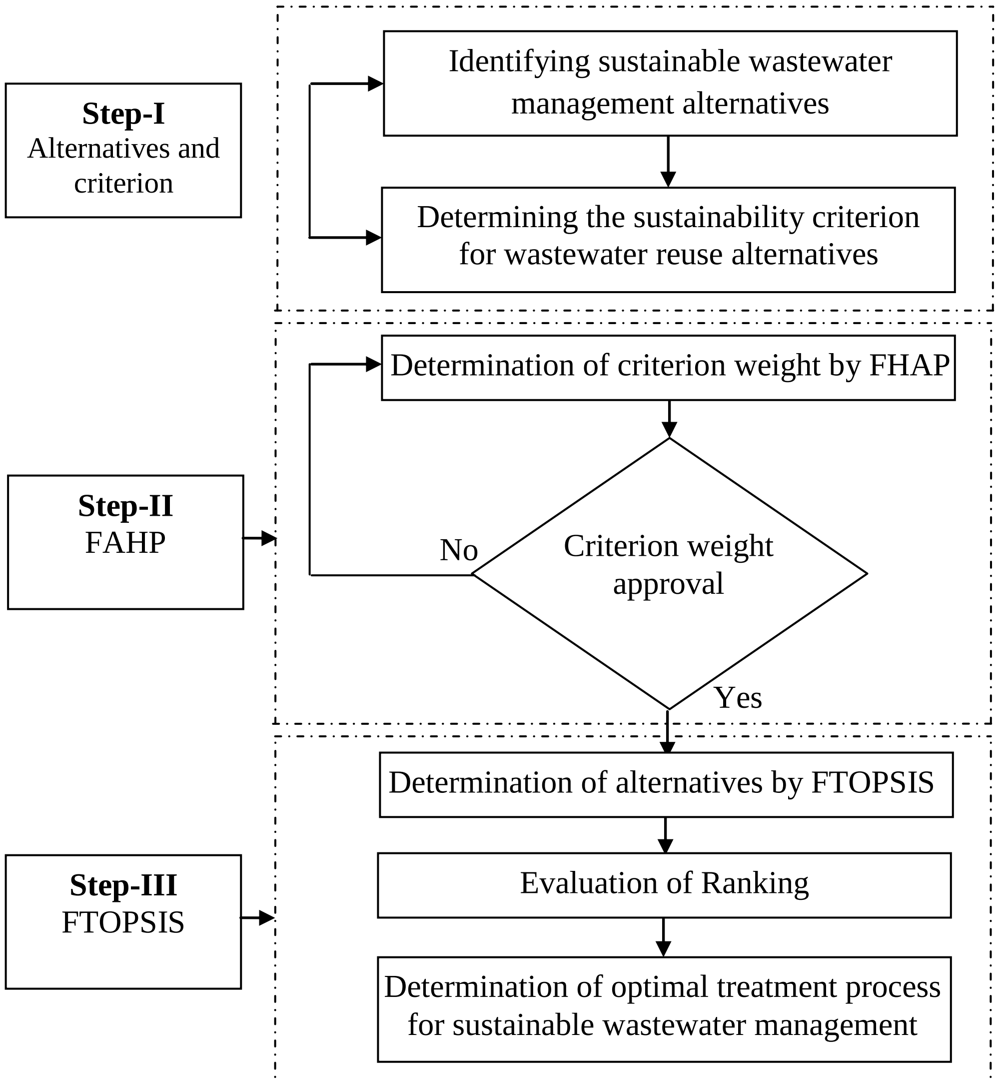

Figure 5.1. Proposed methodology

5.1.1. Fuzzy set theory

Fuzzy set theory was developed by Zadeh [368] a valuable mathematical tool used to strengthen the effectiveness of the decision making techniques. This theory was developed to incorporate ambiguities, vagueness and uncertainties associated with decision maker's subjective judgments. A fuzzy set is defined as:

$$\mathrm{X} = \{(\chi, \xi(\chi)), \chi \in \mu\} \tag{5.1}$$

Where χ will define on real line for universe of discourse μ and $\xi(\chi)$ represent a membership function having defined value in between 0 to 1. In present paper triangular fuzzy numbers were utilized and memberships function for a triangular fuzzy number $(\hbar = h_1, k_1, l_1)$ was defined as:

$$\xi(\chi) = \begin{Bmatrix} 0, & \chi < h \\ \dfrac{\chi - h}{k - h} & h \le \chi \le k \\ \dfrac{\chi - l}{k - l} & k \le \chi \le l \\ 0 & \chi > l \end{Bmatrix} \tag{5.2}$$

The various operation laws of two triangular fuzzy numbers such as $\hbar = h_1, k_1, l_1$ and $\lambda = h_2, k_2, l_2$ were presented in Table 5.2 [369]. Moreover for determining the distance between these triangular fuzzy numbers vertex method was used as:

$$D(\hbar, \lambda) = \sqrt{\frac{1}{3}}\left[(h_1 - h_2) + (k_1 - k_2) + (l_1 - l_2)\right] \tag{5.3}$$

As there are various uncertainties in textile wastewater management system making it a difficult task for a designer to assign a precise score to the selected alternative. Hence, the concept of linguistic variable was introduced. It was reported in literature that linguistic values such as low, very low, medium, very high, high etc. proves very useful in solving many complex decision making problems. These linguistic values can be convertible in triangular fuzzy numbers as presented in Table 5.3.

Table 5.2. Operational laws of triangular fuzzy numbers.

Operational Laws	Description
Addition	$\hbar + \lambda = (h_1, k_1, l_1) + (h_2, k_2, l_2) = (h_1 + h_2, k_1 + k_2, l_1 + l_2)$
Subtraction	$\hbar - \lambda = (h_1, k_1, l_1) - (h_2, k_2, l_2) = (h_1 - h_2, k_1 - k_2, l_1 - l_2)$
Multiplication	$\hbar \times \lambda = (h_1, k_1, l_1) \times (h_2, k_2, l_2) = (h_1 \times h_2, k_1 \times k_2, l_1 \times l_2)$
Division	$\hbar / \lambda = (h_1, k_1, l_1)/(h_2, k_2, l_2) = (h_1 / h_2, k_1 / k_2, l_1 / l_2)$
Inverse	$(\hbar)^{-1} = (h_1, k_1, l_1)^{-1} = \left(\dfrac{1}{h_1}, \dfrac{1}{k_1}, \dfrac{1}{l_1}\right)$

Table 5.3. Linguistic values and fuzzy numbers

Linguistic values	Fuzzy numbers
Very low (VL)	(0, 0.10, 0.25)
Low (L)	(0.15, 0.30, 0.45)
Medium (M)	(0.35,0.50,0.65)
High (H)	(0.55, 0.70, 0.85)
Very high (VH)	(0.75, 0.90, 1)

5.1.2. Step I: Identification of alternative and criterion

In this step, the various alternatives and criterions used in the assessment of the sustainability of textile waste-water management were identified. Alternatives were selected from the literature while criterions were determined by the expert team consisting members from both industry and academia.

5.1.3. Step II: FAHP for criterion weight determination

Saaty [369] clearly defined the hierarchy process approach was a structured technique used mathematics calculation for criterion priority or weight determination. FAHP was initiated by structuring a pair-wise comparison matrix on the basis of nine point scale presented in Table 5.4. Generally, for n criterions the pair-wise comparison matrix (ζ_{nn}) was given as:

$$\zeta_{nn} = \begin{bmatrix} \zeta_{11} & \zeta_{12} & \cdots & \zeta_{1n} \\ \zeta_{21} & \zeta_{22} & \cdots & \zeta_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \zeta_{n1} & \zeta_{n2} & \cdots & \zeta_{nn} \end{bmatrix} \quad \zeta_{ii} = 1, \zeta_{ji} = \frac{1}{\zeta_{ij}}, \zeta_{ij} \neq 0 \tag{5.4}$$

Where the importance of ith with respect to jth criterion was represent by ζ_{ij} .

Further each entity of this comparison matrix was converted to linguistic values with the help of Table 5.4. The linguistic comparison matrix was given as:

Table 5.4. The fundamental relational scale for pair-wise comparisons

Absolute scale	Definition	Explanation	FUZZY numbers
1	Equal importance	Both the activities equally contributed to the objective	(1,1,1)
2	Weak importance	favor slightly one activity over another as per experts opinion and judgment	(1,2,3)
3	Moderate importance	Moderately favor one activity over another as per experts opinion and judgment	(2,3,4)
4	Preferable	Experience and judgment strongly support one activity over another	(3,4,5)
5	Strong importance	Experts opinion and judgment strongly favor one activity over another	(4,5,6)
6	Fairly importance	Experts opinion and judgment strongly favor one activity over another	(5,6,7)
7	Very importance	An activity is very strongly favored	(6,7,8)
8	Absolute	An activity is absolutely favored	(7,8,9)
9	Extreme importance	highest possible order of affirmation one activity over another is of the	(8,9,10)

$$\bar{\zeta}_{nn} = \begin{bmatrix} \bar{\zeta}_{11} & \bar{\zeta}_{12} & \cdots & \bar{\zeta}_{1n} \\ \bar{\zeta}_{21} & \bar{\zeta}_{22} & \cdots & \bar{\zeta}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \bar{\zeta}_{n1} & \bar{\zeta}_{n2} & \cdots & \bar{\zeta}_{nn} \end{bmatrix} \quad \bar{\zeta}_{ii} = 1, \bar{\zeta}_{ji} = \frac{1}{\bar{\zeta}_{ij}}, \bar{\zeta}_{ij} \neq 0 \tag{5.5}$$

Thereafter weight of each criterion was computed by using geometric mean method. For ith criterion the weight was calculated as:

$$\bar{\sigma}_i = \left[\bar{\zeta}_{i1} \times \bar{\zeta}_{i2} \times \cdots \times \bar{\zeta}_{in}\right]^{1/n} \tag{5.6}$$

$$\varpi_i = \bar{\sigma}_i \times \left[\bar{\sigma}_1 + \bar{\sigma}_2 + \cdots + \bar{\sigma}_n\right]^{-1} \tag{5.7}$$

Now this computed weight will be defined in terms of triangular fuzzy numbers. If $\varpi_i = (p\varpi_i, q\varpi_i, r\varpi_i)$ is the fuzzy weight triangular number, then non-fuzzy weight (NFW) was calculated using following equation.

$$\text{NFW} = \left(\frac{(r-p)+(q-p)}{3} + p \right) \tag{5.8}$$

Thereafter, the average eigenvalue (λ_{max}) was calculated by multiplying NFW values to the $\bar{\zeta}_{nn}$ in column-wise.

The superiority of the FAHP was rigorously associated with the consistency of the $\bar{\zeta}_{nn}$. The consistency was performed by computing consistency ratio (C.R.) as:

$$\text{C.R.} = \frac{\lambda_{\max} - n}{n-1} \times \frac{1}{RI} \tag{5.9}$$

Where RI the random index of the matrix and its value was decided according the order of the constructed $\bar{\zeta}_{nn}$. For perfectly consistence matrix the C.R. should be remains ≥ 0.1.

5.1.4. Step- III: FTOPSIS for ranking evaluation

In this step, a fuzzy decision matrix between alternatives and criterion was constructed in terms of linguistic values as presented in Table 5.4. If there were m alternatives to be evaluated against n criterions then fuzzy decision matrix was constructed as:

$$D_{ij} = \begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1n} \\ s_{21} & s_{22} & \cdots & s_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ s_{m1} & s_{m2} & \cdots & s_{mn} \end{bmatrix} \quad i = 1, 2, \cdots m; \quad j = 1, 2, \cdots n \tag{5.10}$$

The fuzzy decision matrix was constructed in terms of linguistic values representing triangular fuzzy numbers and generally belongs to 0-1; thus, there was no need to normalize this fuzzy decision matrix. Now computed weights were used to construct weighted fuzzy decision matrix as:

$$\overline{D_{ij}} = D_{ij} \times \varpi_i \tag{5.11}$$

After defining weighted fuzzy decision matrix, positive (φ^+) and negative (φ^-) fuzzy ideal solution were identified as:

$$\varphi^+ = \left(\overline{D_1}^+, \overline{D_2}^+, \cdots \overline{D_n}^+ \right) \text{ and } \varphi^- = \left(\overline{D_1}^-, \overline{D_2}^-, \cdots \overline{D_n}^- \right) \tag{5.12}$$

$$\overline{D}_j^{+} = \begin{cases} \underset{i}{\overset{m}{Max}}\, \overline{D}_{ij} \text{ if } j \text{ is a benefit criterion} \\ \\ \underset{i}{\overset{m}{Min}}\, \overline{D}_{ij} \text{ if } j \text{ is a cost criterion} \end{cases} \text{, and}$$

$$\overline{D}_j^{-} = \begin{cases} \underset{i}{\overset{m}{Min}}\, \overline{D}_{ij} \text{ if } j \text{ is a benefit criterion} \\ \\ \underset{i}{\overset{m}{Max}}\, \overline{D}_{ij} \text{ if } j \text{ is a cost criterion} \end{cases} \qquad \text{for } j = 1, 2, \ldots, n \qquad (5.13)$$

Thereafter, for every alternative distance from φ^{+} and φ^{-} was determined as:

$$\Theta_i^{+} = \sqrt{\sum_{j=1}^{n} \left(\overline{D}_j^{+} - \overline{D}_{ij} \right)^2} \text{, and}$$

$$\Theta_i^{-} = \sqrt{\sum_{j=1}^{n} \left(\overline{D}_{ij} - \overline{D}_j^{-} \right)^2} \qquad \text{for } i = 1, 2, \ldots, m \qquad (5.14)$$

Now, closeness coefficient values were computed and for ith alternative the closeness coefficient (Ω_i) was determined as:

$$\Omega_i = \frac{\Theta_i^{+}}{\Theta_i^{+} + \Theta_i^{-}} \text{, for i = 1, 2. . . m} \qquad (5.15)$$

5.2. Case study

The main purpose of case study was to identify the treatment alternative to improve overall performance of the textile manufacturing sectors. In this study, five experts were selected to evaluate the proposed criterion for sustainable development of textile waste-water treatment in various textile sectors. Three of the experts were technical persons from the production managers of textile sectors and two of experts were from the academic groups working on the various treatment technology in their research work specifically environment and management fields. The same group already published literature on textile waste-water with and without treatment [244] and finally fuzzy linguistic terms were incorporated by the selected decision-makers from the five different textile industries in India. Literature reveals that combination of traditional process was preferred for waste-water treatment. Hence, there combinations namely P-1 (combination of physical and chemical processes), P-2 (combination of physical and biological processes), P-3 (combination of biological and chemical processes) and P-4 (combination of physical, chemical and biological processes) were selected as alternative. The importance of key criterion and indicators which associated with the sustainability of textile waste-water management mainly depends upon eleven primary criterions as far as Indian textile sectors concerned. Labor input in the textile industry [370] directly or indirectly improved the textile industry productivity [371] that purely based upon the types of policy implication [372], waste-water treatment and disposal [373], textile reuse and recycling [374], dyes and additives [375] respectively. Similarly, for improvement of sustainability-related performance [376], most of the textile sectors nowadays mainly depend on the following three-dimensional criterion such as economic performance [377], environmental impact for an environmentally friendly way of production [378], operational performance [377] respectively. There was an increase in energy consumption and carbon dioxide emissions [379] mainly proportional to the increase of expansion of economic activities as well as an increase in population size worldwide. Finally, eleven important criterions to be used for sustainability of textile wastewater management were established. In the present analysis 264 industries have been selected in all the parts of the country and observed that nearly 39 industries following Physical and Chemical treatment processes, 28 Industries following Physical and biological processes, 120 Industries following Biological and chemical processes and 77 Industries following Physical, chemical and biological processes respectively. Based upon their treatment processes the following data were collected through survey as reported in Table 5.5 and then the overall mean was calculated from the survey mean (Table 5.5). After survey analysis again reselected each treatment category two companies were selected for further analysis and the detained analysis was mentioned in Table 5.5 by designating the company names as A, B, C, D, E, F, G and H respectively. From Table 5.5 it was observed that the survey overall mean was slightly less than the overall company mean.

Table 5.5. Comparisons of Survey overall mean and selected companies overall mean

Types of treatment Process	Attributes	Survey mean value	Overall mean	Company A (overall mean)	Company B (overall mean)	Company C (overall mean)	Company D (overall mean)	Company E (overall mean)	Company F (overall mean)	Company G (overall mean)	Company H (overall mean)
Physical and Chemical processes (39 Industries)	Labor input in textile industry	4.231	3.93	5	5	---	---	---	---	---	---
	Policy Implication	4.244		5	5	---	---	---	---	---	---
	Textile reuse and recycle	3.865		4	5	---	---	---	---	---	---
	Dyes and additives	3.853		4	5	---	---	---	---	---	---
	Wastewater treatment and disposal	3.654		4	4	---	---	---	---	---	---
	Energy consumption and carbon dioxide emission	4.199		5	5	---	---	---	---	---	---
	Textile industry productivity	4.321		5	5	---	---	---	---	---	---
	Improvement of sustainable related performance	3.551		4	4	---	---	---	---	---	---
	Economic Performance	3.788		4	4	---	---	---	---	---	---
	Environmental Impact	3.571		4	4	---	---	---	---	---	---
	Operational Performance	3.955		4	4	---	---	---	---	---	---
Company A and B (overall mean)				4.364	4.545						

	Labor input in textile industry	3.804		---	---	4	5	---	---	---	---
	Policy Implication	3.911		---	---	4	5	---	---	---	---
	Textile reuse and recycle	3.750		---	---	4	5	---	---	---	---
	Dyes and additives	3.714		---	---	4	4	---	---	---	---
	Wastewater treatment and disposal	3.848		---	---	4	4	---	---	---	---
Physical and biological processes (28 Industries)	Energy consumption and carbon dioxide emission	4.259		---	---	5	5	---	---	---	---
	Textile industry productivity	4.241	3.906	---	---	5	5	---	---	---	---
	Improvement of sustainable related performance	3.902		---	---	5	4	---	---	---	---
	Economic Performance	3.875		---	---	5	4	---	---	---	---
	Environmental Impact	3.661		---	---	4	4	---	---	---	---
	Operational Performance	4.009		---	---	5	5	---	---	---	---
			Company C and D (overall mean)			4.455	4.545				
Biological and chemical processes (120 Industries)	Labor input in textile industry	4.390		---	---	---	---	5	5	---	---
	Policy Implication	4.060		---	---	---	---	4	4		
	Textile reuse and	4.290		---	---		---	4	4	---	---

	recycle										
	Dyes and additives	3.860		---	---	---	---	4	4	---	---
	Wastewater treatment and disposal	3.840		---	---	---	---	4	5	---	---
	Energy consumption and carbon dioxide emission	4.490	4.053	---	---	---	---	5	5	---	---
	Textile industry productivity	4.560		---	---	---	---	4	5	---	---
	Improvement of sustainable related performance	3.650		---	---	---	---	4	4	---	---
	Economic Performance	4.380		---	---	---	---	5	5	---	---
	Environmental Impact	3.710		---	---	---	---	4	5	---	---
	Operational Performance	3.360		---	---	---	---	4	4	---	---
					Company E and F (overall mean)			4.273	4.545		
Physical, chemical and biological processes (77 Industries)	Labor input in textile industry	4.013		---	---	---	---	---	---	5	5
	Policy Implication	3.912		---	---	---	---	---	---	4	4
	Textile reuse and recycle	3.620		---	---	---	---	---	---	4	4
	Dyes and additives	3.744		---	---	---	---	---	---	4	5
	Wastewater treatment and	3.831		---	---	---	---	---	---	4	5

disposal										
Energy consumption and carbon dioxide emission	4.127		---	---	---	---	---	---	5	5
Textile industry productivity	4.221	3.871	---	---	---	---	---	---	5	5
Improvement of sustainable related performance	3.438		---	---	---	---	---	---	5	5
Economic Performance	3.977		---	---	---	---	---	---	4	5
Environmental Impact	3.562		---	---	---	---	---	---	4	4
Operational Performance	4.133		---	---	---	---	---	---	5	5
					Company G and H (overall mean)				4.455	4.727

On five-point scale: 1 -strongly disagree, 5 - strongly agree.

5.3. Calculation of criterion weight

The weight of the different criterions utilized in this ranking procedure was determined by utilizing the FAHP technique. Table 5.6 was useful to construct the pair-wise comparison matrix as per selected criterion for sustainability of textile waste-water management. These eleven key criterions were arranged in a square matrix as shown in Table 5.6 by putting their relative importance values. These numbers were inserted in the matrix as per expert's opinion and through offline survey questioners. After that in the Pair-wise comparison matrix the prepared fuzzy numbers was incorporated as shown in Table 5.7.

Table 5.6. Pair-wise comparison matrix

	C-1	C--2	C--3	C--4	C--5	C--6	C--7	C--8	C--9	C--10	C--11
C--1	1	1	1	1	2	3	4	7	8	9	9
C--2	1	1	1	1	2	3	5	5	8	9	9
C--3	1	1	1	1	2	3	3	5	7	7	9
C--4	1	1	1	1	1	2	3	4	6	7	8
C--5	1/2	1/2	1/2	1	1	1	3	3	4	5	6
C--6	1/3	1/3	1/3	1/2	1	1	1	3	3	3	4
C--7	1/4	1/5	1/3	1/3	1/3	1	1	1	2	3	3
C--8	1/7	1/5	1/5	1/4	1/3	1/3	1	1	1	2	3
C--9	1/8	1/8	1/7	1/6	1/4	1/3	1/2	1	1	1	1
C--10	1/9	1/9	1/7	1/7	1/5	1/3	1/3	1/2	1	1	1
C--11	1/9	1/9	1/9	1/8	1/6	1/4	1/3	1/3	1	1	1

As per Eq. 5.6 the fuzzy geometric mean of all the eleven key criterions were calculated as shown in Table 5.8 and their respective fuzzy weights were calculated as shown in Table 5.8 by using Eq. 5.7. After that the best non fuzzy weight (NFW) was calculated by using Eq. 5.8 to rank the key criterion in the descending order. The criterion has larger NFW value was nominated as a grater significant impact as compared with other criterion. In the present study, labour input in the textile industry shows maximum NFW value that clearly indicated that in any sector including textile sector labor input has major contribution to improve the quality of the product output simultaneously also helps to achieve sustainability in the textile manufacturing sectors.

Once the NFW value was calculated with the help of Eq. 5.8 in row-wise, these NFW values were multiplied to the pair-wise comparison matrix (Table 5.4) in column-wise as shown in Table 5.9 for estimation of row sum and eigenvalue (row sum/NFW). Finally, λ_{max} random index (R.I., Table 5.10) used to calculate the consistency rate (C.R.) as presented in Table 5.11. Saaty [369] suggests that consistency index value less than 0.1 indicates the reported data were in line with the desired outcome as well as shows the consistency of the matrix. The C.R. value is less than 0.1 that indicated the estimate was accepted otherwise a new set of modified comparison matrix was solicited.

Table 5.7. Pair-wise comparison matrix in term of fuzzy numbers

	C-1	C--2	C--3	C--4	C--5	C--6	C--7	C--8	C--9	C--10	C--11
C--1	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1.2,3)	(2,3,4)	(3,4,5)	(6,7,8)	(7,8,9)	(8,9,10)	(8,9,10)
C--2	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1.2,3)	(2,3,4)	(4,5,6)	(4,5,6)	(7,8,9)	(8,9,10)	(8,9,10)
C--3	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1.2,3)	(2,3,4)	(2,3,4)	(4,5,6)	(6,7,8)	(6,7,8)	(8,9,10)
C--4	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1.2,3)	(2,3,4)	(3,4,5)	(5,6,7)	(6,7,8)	(7,8,9)
C--5	(0.333, 0.5,1)	(0.333, 0.5,1)	(0.333, 0.5, 1)	(1,1,1)	(1,1,1)	(1,1,1)	(2,3,4)	(2,3,4)	(3,4,5)	(4,5,6)	(5,6,7)
C--6	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.25,0.333, 0.5)	(0.333,0.5, 1)	(1,1,1)	(1,1,1)	(1,1,1)	(2,3,4)	(2,3,4)	(2,3,4)	(2,3,4)
C--7	(0.2,0.25, 0.333)	(0.167,0.2, 0.25)	(0.25,0.333, 0.5)	(0.25,0.333, 0.5)	(0.25,0.333, 0.5)	(1,1,1)	(1,1,1)	(1,1,1)	(1.2,3)	(2,3,4)	(2,3,4)
C--8	(0.125,0.143, 0.167)	(0.167,0.2, 0.25)	(0.167,0.2, 0.25)	(0.2,0.25, 0.333)	(0.25,0.333, 0.5)	(0.25,0.333, 0.5)	(1,1,1)	(1,1,1)	(1,1,1)	(1.2,3)	(2,3,4)
C--9	(0.111,0.125, 0.143)	(0.111, 0.125, 0.143)	(0.125,0.143, 0.167)	(0.14,0.166, 0.2)	(0.2,0.25, 0.333)	(0.25,0.333, 0.5)	(0.333,0.5, 1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
C--10	(0.1,0.111, 0.125)	(0.1,0.111, 0.125)	(0.125,0.149, 0.167)	(0.125,0.143, 0.167)	(0.17,0.2, 0.25)	(0.25,0.333, 0.5)	(0.25,0.333, 0.5)	(0.333,0.5, 1)	(1,1,1)	(1,1,1)	(1,1,1)
C--11	(0.1,0.111, 0.125)	(0.1,0.111, 0.125)	(0.1,0.111,0. 125)	(0.11,0.125, 0.14)	(0.14,0.166, 0.2)	(0.2,0.25, 0.333)	(0.25,0.333, 0.5)	(0.25,0.3, 0.5)	(1,1,1)	(1,1,1)	(1,1,1)

Table 5.8. Calculation of Best Non fuzzy weight Performance

Criterion	$\overline{\zeta}_{i1} \times \overline{\zeta}_{i2} \times \cdots \times \overline{\zeta}_{in}$	$\overline{\sigma}_i = \left[\overline{\zeta}_{i1} \times \overline{\zeta}_{i2} \times \cdots \times \overline{\zeta}_{in}\right]^{1/n}$ (**Fuzzy Geom. Mean**)	$\varpi_i = \overline{\sigma}_i \times \left[\overline{\sigma}_1 + \overline{\sigma}_2 + \cdots + \overline{\sigma}_n\right]^{-1}$ **Fuzzy weight**	[(r-p)+(q-p)]/3+p **NFW**
C--1	(16128, 108864, 432000)	(2.415, 2.873, 3.257)	(0.132, 0.186, 0.255)	0.19117
C--2	(14336, 97200,388800)	(2.389, 2.844, 3.226)	(0.131, 0.184, 0.253)	0.189252
C--3	(4608, 39690, 184320)	(2.155, 2.621, 3.014)	(0.118, 0.170, 0.236)	0.174638
C--4	(1260, 8064, 30240)	(1.915, 2.267, 2.557)	(0.105, 0.147, 0.201)	0.150679
C--5	(8.888889, 135, 3360)	(1.220, 1.563, 2.094)	(0.067, 0.101, 0.164)	0.110692
C--6	(0.125, 2, 40)	(0.828, 1.065, 1.399)	(0.045, 0.069, 0.110)	0.074642
C--7	(0.002083,0.033333,0.5)	(0.570, 0.734, 0.939)	(0.031, 0.048, 0.074)	0.050773
C--8	(8.68E-05, 0.00068, 0.010417)	(0.427, 0.515, 0.660)	(0.023, 0.033, 0.052)	0.036153
C--9	(3.67E-06, 1.55E-05, 0.000113)	(0.320, 0.365, 0.437)	(0.018, 0.024, 0.034)	0.025151
C--10	(5.43E-07, 2.8E-06,2.71E-05)	(0.269, 0.312, 0.384)	(0.015, 0.020, 0.030)	0.021687
C--11	(1.98E-07, 7.94E-07, 4.65E-06)	(0.246, 0.279, 0.327)	(0.013, 0.018, 0.026)	0.019038
	SUM	**(12.75294,15.43757, 18.29449)**		

Table 5.9. Pair-wise comparison matrix after putting the BNP value

Criteria	C-1	C--2	C--3	C--4	C--5	C--6	C--7	C--8	C--9	C--10	C--11
C--1	0.191	0.189	0.175	0.151	0.221	0.224	0.203	0.253	0.201	0.195	0.171
C--2	0.191	0.189	0.175	0.151	0.221	0.224	0.254	0.181	0.201	0.195	0.171
C--3	0.191	0.189	0.175	0.151	0.221	0.224	0.152	0.181	0.176	0.152	0.171
C--4	0.191	0.189	0.175	0.151	0.111	0.149	0.152	0.145	0.151	0.152	0.152
C--5	0.096	0.095	0.087	0.151	0.111	0.075	0.152	0.108	0.101	0.108	0.114
C--6	0.064	0.063	0.058	0.075	0.111	0.075	0.051	0.108	0.075	0.065	0.076
C--7	0.048	0.038	0.058	0.050	0.037	0.075	0.051	0.036	0.050	0.065	0.057
C--8	0.027	0.038	0.035	0.038	0.037	0.025	0.051	0.036	0.025	0.043	0.057
C--9	0.024	0.024	0.025	0.025	0.028	0.025	0.025	0.036	0.025	0.022	0.019
C--10	0.021	0.021	0.025	0.022	0.022	0.025	0.017	0.018	0.025	0.022	0.019
C--11	0.021	0.021	0.019	0.019	0.018	0.019	0.017	0.012	0.025	0.022	0.019

Table 5.10. Values of the Random Index (R.I.) for problems ($m \leq 15$)

Matrix order	1	2	3	4	5	6	7	8
R.I.	0		0.52	0.90	1.12	1.25	1.35	1.42
Matrix order	9		10	11	12	13	14	15
R.I.	1.46		1.49	1.52	1.54	1.56	1.58	1.59

Table 5.11. Results of comparison matrix by using FAHP

Criterion	Row sum	Calculation of Eigen value	Fuzzy weight Criteria	Best Non-fuzzy weight (NFW)	λmax, RI	Consistency Ratio (CR)
C--1	2.174942	11.37699025	(0.132, 0.186, 0.255)	0.19117		
C--2	2.15341	11.37851351	(0.131, 0.184, 0.253)	0.189252		
C--3	1.983339	11.35688039	(0.118, 0.170, 0.236)	0.174638		
C--4	1.717664	11.39950818	(0.105, 0.147, 0.201)	0.150679		
C--5	1.197588	10.81912228	(0.067, 0.101, 0.164)	0.110692		
C--6	0.82159	11.00714804	(0.045, 0.069, 0.110)	0.074642		
C--7	0.565024	11.12833325	(0.031, 0.048, 0.074)	0.050773	**λmax= 11.17943874**	C.R.=
C--8	0.412101	11.39891372	(0.023, 0.033, 0.052)	0.036153		0.01180518
C--9	0.277583	11.03669386	(0.018, 0.024, 0.034)	0.025151		
C--10	0.236639	10.9117268	(0.015, 0.020, 0.030)	0.021687	R.I.= 1.52(Table 5.10)	
C--11	0.212469	11.15999586	(0.013, 0.018, 0.026)	0.019038		
sum		122.9738262				
Avg. of eigen value=λmax		**11.17943874**				

5.4. FTOPSIS for alternative ranking

Table 5.12 shows the linguistics fuzzy evaluation matrix filled with the help of selected decision maker during survey. After that the defined fuzzy numbers have been incorporated in the fuzzy decision matrix for further analysis as shown in Table 5.13. Fuzzy weighted evaluation matrix was calculated by multiplying criterion weight with the fuzzy decision matrix by using Eq. 5.11 for determination of fuzzy positive ideal solution (φ^+) and fuzzy negative ideal solution (φ^-) and presented in Table 5.14. At the end, the closeness coefficient Ω_i and ranking of the alternative were calculated by using Eq. 5.15 and the alternatives were ranked as per their Ω_i value. The alternative having highest Ω_i denoted as rank one and accordingly arranged ranking rest alternatives. In this study, biological and chemical treatment techniques were shown effective treatment techniques for sustainability of textile waste-water recycling among selected techniques (Table 5.15).

Table 5.12. Linguistic fuzzy evaluation matrix

Alternatives	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10	C-11
P-1(P+C)	M	H	H	H	L	H	L	M	VH	L	L
P-2(P+B)	M	H	H	H	M	H	L	M	H	L	L
P-3(B+C)	M	M	M	M	H	M	M	H	H	M	M
P-4(P+C+B)	H	L	M	M	VH	L	H	VH	L	M	M

Table 5.13. Fuzzy decision matrix

Alternatives	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10	C-11
P-1 (P+C)	(0.35, 0.5, 0.65)	(0.55, 0.7, 0.85)	(0.55, 0.7, 0.85)	(0.55, 0.7, 0.85)	(0.15, 0.3, 0.45)	(0.55, 0.7, 0.85)	(0.15, 0.3, 0.45)	(0.35, 0.5, 0.65)	(0.75, 0.9, 1)	(0.15, 0.3, 0.45)	(0.15, 0.3, 0.45)
P-2 (P+B)	(0.35, 0.5, 0.65)	(0.55, 0.7, 0.85)	(0.55, 0.7, 0.85)	(0.55, 0.7, 0.85)	(0.35, 0.5, 0.65)	(0.55, 0.7, 0.85)	(0.15, 0.3, 0.45)	(0.35, 0.5, 0.65)	(0.55, 0.7, 0.85)	(0.15, 0.3, 0.45)	(0.15, 0.3, 0.45)
P-3 (B+C)	(0.35, 0.5, 0.65)	(0.35, 0.5, 0.65)	(0.35, 0.5, 0.65)	(0.35, 0.5, 0.65)	(0.55, 0.7, 0.85)	(0.35, 0.5, 0.65)	(0.35, 0.5, 0.65)	(0.55, 0.7, 0.85)	(0.55, 0.7, 0.85)	(0.35, 0.5, 0.65)	(0.35, 0.5, 0.65)
P-4 (P+C+B)	(0.55, 0.7, 0.85)	(0.15, 0.3, 0.45)	(0.35, 0.5, 0.65)	(0.35, 0.5, 0.65)	(0.75, 0.9, 1)	(0.15, 0.3, 0.45)	(0.55,0.7, 0.85)	(0.75, 0.9, 1)	(0.15, 0.3, 0.45)	(0.35, 0.5, 0.65)	(0.35, 0.5, 0.65)
Weight criteria	(0.132, 0.186, 0.255)	(0.131, 0.184, 0.253)	(0.118, 0.170, 0.236)	(0.105, 0.147, 0.201)	(0.067, 0.101, 0.164)	(0.045, 0.069, 0.110)	(0.031, 0.048, 0.074)	(0.023, 0.033, 0.052)	(0.018, 0.024, 0.034)	(0.015, 0.020, 0.030)	(0.013, 0.018, 0.026)

Table 5.14. Fuzzy weighted evaluation matrix

Alternatives	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10	C-11
P-1(P+C)	(0.046, 0.093, 0.166)	(0.072, 0.129, 0.215)	(0.065, 0.119, 0.201)	(0.058, 0.103, 0.170)	(0.010, 0.030, 0.074)	(0.025, 0.048, 0.093)	(0.005, 0.014, 0.033)	(0.008, 0.017, 0.034)	(0.013, 0.021, 0.034)	(0.002, 0.006, 0.014)	(0.002, 0.005, 0.012)
P-2(P+B)	(0.046, 0.093, 0.166)	(0.072, 0.129, 0.215)	(0.065, 0.119, 0.201)	(0.058, 0.103, 0.170)	(0.023, 0.051, 0.107)	(0.025, 0.048, 0.093)	(0.005, 0.014, 0.033)	(0.008, 0.017, 0.034)	(0.010, 0.017, 0.029)	(0.002, 0.006, 0.014)]	(0.002, 0.005, 0.012)
P-3(B+C)	(0.046, 0.093, 0.166)	(0.046, 0.092, 0.164)	(0.041, 0.085, 0.154)	(0.037, 0.073, 0.130)	(0.037, 0.071, 0.140)	(0.016, 0.034, 0.071)	(0.011, 0.024, 0.048)	(0.013, 0.023, 0.044)	(0.010, 0.017, 0.029)	(0.005, 0.010, 0.020)	(0.005, 0.009, 0.017)
P-4 (P+C+B)	(0.073, 0.130, 0.217)	(0.020, 0.055, 0.114)	(0.041, 0.085, 0.154)	(0.037, 0.073, 0.130)	(0.050, 0.091, 0.164)	(0.007, 0.021, 0.049)	(0.017, 0.033, 0.063)	(0.018, 0.030, 0.052)	(0.003, 0.007, 0.015)	(0.005, 0.010, 0.020)	(0.005, 0.009, 0.017)
φ^{+}	$\overline{D}_1^{+}$ =(0,0,0)	$\overline{D}_2^{+}$ =(0,0,0)	$\overline{D}_3^{+}$ =(0,0,0)	$\overline{D}_4^{+}$ =(0,0,0)	$\overline{D}_5^{+}$ =(0,0,0)	$\overline{D}_6^{+}$ =(1,1,1)	$\overline{D}_7^{+}$ =(1,1,1)	$\overline{D}_8^{+}$ =(1,1,1)	$\overline{D}_9^{+}$ =(0,0,0)	$\overline{D}_{10}^{+}$ =(1,1,1)	$\overline{D}_{11}^{+}$ =(1,1,1)
φ^{-}	$\overline{D}_1^{-}$ =(1,1,1)	$\overline{D}_2^{-}$ =(1,1,1)	$\overline{D}_3^{-}$ =(1,1,1)	$\overline{D}_4^{-}$ =(1,1,1)	$\overline{D}_5^{-}$ =(1,1,1)	$\overline{D}_6^{-}$ =(0,0,0)	$\overline{D}_7^{-}$ =(0,0,0)	$\overline{D}_8^{-}$ =(0,0,0)	$\overline{D}_9^{-}$ =(1,1,1)	$\overline{D}_{10}^{-}$ =(0,0,0)	$\overline{D}_{11}^{-}$ =(0,0,0)

Table 5.15. The fuzzy closeness index and ranking of alternatives

Alternatives	Θ_i^{+}	Θ_i^{-}	Ω_i	**Ranking**
P-1(P+C)	4.865185722	4.997476916	0.506707	3
P-2(P+B)	4.86766177	4.964593144	0.504929	4
P-3(B+C)	4.824375494	5.104061492	**0.514085**	**1**
P-4(P+C+B)	4.828110105	5.091533658	0.513278	2

Chapter summery

This study mainly focuses on the significant key criterions to improve the sustainability of textile waste-water management and simultaneously implementation of FAHP to identify the best suitable criterion.

The next chapter describes the concluding remarks and future scope of this research work on sustainability of textile wastewater management

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Chapter-6

Concluding remarks and perspective

6.1. Concluding Remarks

1. Actually, the need of harmony between environment, society and economy has always been documented by different cultures. It is almost an inconsistency that the environmental issue has become an important only in the last era, since every kind of human activity has an impact obviously on natural eco-systems.
2. In particular, economic activity is one of the mere transformations of raw materials and people labor in marketable outputs within the environmental context. Anyway, the actual background of advanced technology, global industrialization and information to the society that modifies the approaches and actions that have to be taken to deal with sustainability.
3. The conceptual framework produces a sustainable benchmark to the society; the manufacturing industry as well as policymakers specifically textile industries along with other allied organizations.
4. The present textile water-waste management system suffers huge loss in terms of health hazards, product, technology, operational performance, and economic conditions respectively. These waste can be reduced by developing advanced technology, create better labor policy, reuse of textile wastes or effluents for construction as well as agriculture applications.
5. Exhaustive literature has been collected to identify the research gap in textile manufacturing sectors and then identify the key sustainable wastewater management practices to improve the performance of sustainable output performance.
6. Conceptual framework has been proposed based on the available literature as well as through experts opinion, and the key aspects to be considered in this research work such as: Policy implications, Dyes and additives, Energy consumption and carbon dioxide emissions, Wastewater treatment and disposal, Labor input in the textile industry, Textile reuse, Textile industry productivity, Economic performance,

Improvement of sustainability-related performance, and recycling, Environmental impact, and Operational performance respectively.

7. Finally, we acknowledge that this framework needs further analysis for checking the reliability and validity of the conceptual framework by applying empirical framework based on the survey questionnaire data. We believe that this study definitely provides sufficient information to the manufacturing sectors irrespective of the type of sector because by implementing the empirical analysis will provide a better correlation between the STWM practices and sustainable output performance.
8. The finding of this thesis work was a successful development of a structural equation model for the understanding of real problem for the sustainability of textile wastewater management in textile sectors. This study also highly helpful specifically the waste management researchers for identification of major variables along with their sub-variables during manufacturing of textile products.
9. The total variance was greater than 67 percentages with more than one eigenvalues as per analysis concluded in chapter 4. The skewness and kurtosis were in the range of +/-1.5 for each sub-variables in the present analysis. The squared multiple correlations (r^2) values were adequately higher (ranging from 0.290 to 0.960). Hence, all the constructed eleven variables were a good fit due to the squared multiple correlations (r^2) values that confirm that the factors were unidimensional.
10. The KMO values of the factors were lie between the range of 0.80 or 0.90, which was higher than the expected value 0.60 and concluded that the inter-correlation matrix was almost ideal for factor analysis.
11. However, in first-order confirmatory factor analysis, the composite reliability for all the factors was higher than 0.7, and the average variances extracted for one factor was closer to 0.5, but for WTD, the average variance extracted was marginally lower. These results suggest that the internal consistencies of the constructs were satisfactory.
12. In second-order-structural model analysis, the criteria for goodness-of-fit-index (GFI) was 0.843, AGFI was 0.815, normed-fit-index (NFI) was 0.837, comparative fit index (CFI) was 0.924, and the root means square error of approximation (RMSEA) was 0.052 respectively. Hence, it was concluded that the overall

assessment of the criteria for the model fit was acceptable for second-order confirmatory factor analysis in its validation.

13. At the end, for constructing multi-factor analysis after first and second order analysis, the goodness-of-fit-index(GFI) was 0.780, AGFI was acceptable at 0.753, normed-fit-index (NFI) was 0.752, comparative-fit-index (CFI) was 0.870 respectively. The root means square error of approximation (RMSEA) of 0.055 was adequate since it was between 0.00-0.13. Hence, all the indicator sub-variables loaded highly and signed on to their respective factors and therefore, the structural model were positively correlated with each other.
14. Hence, based on the above remarks the proposed structural model concept must be implemented in multiple textile industries or any other sectors were sustainability is a major concern in India as well as other parts of the world, the sustainability of textile wastewater management principle may be considered as a case study analysis.
15. In the present analysis 264 industries have been selected in all the parts of the country and observed that nearly 39 industries following Physical and Chemical treatment processes, 28 Industries following Physical and biological processes, 120 Industries following Biological and chemical processes and 77 Industries following Physical, chemical and biological processes respectively.
16. Based upon their treatment processes the following data were collected through survey and then the overall mean was calculated from the survey mean. After survey analysis again reselected each treatment category two companies were selected for further analysis and the detained analysis was performed by designating the company names as A, B, C, D, E, F, G and H respectively. It was observed that the survey overall mean was slightly less than the overall company mean.
17. As FAHP is one of the potential multi-criterion decisions making method benefit the textile manufacturing sectors by minimizing waste utilization. In the present study, labor input in the textile industry shows maximum BNP value that indicated that in any sector including textile sector labor input has significant contribution to improve the quality of the product output simultaneously helps to achieve sustainability in the textile manufacturing sectors.

18. Similarly, implementation of FTOPSIS in textile sectors specifically for different treatment methodology followed in textile processing industries and concluded that biological and chemical treatment to be suitable for better and efficient methodology as far as textile manufacturing is concerned.
19. In future, this study can be extended by using other decision-making models such as VIKOR, PSI, COPRAS and MOORA to optimize the textile treatment process as well.

6.2. Future Research

1. For future studies on textile waste in several untouched areas are recommended based on the development of the present research work. First-of-all, further more advanced research is needed in the areas of recycling and converting textile waste back into fibers and other useful materials. Hence, research and development of new viable, products and industrial applications for materials made from converted textile waste that could provide important solutions for dealing with textile quantity of waste.
2. Innovations in these areas could also provide opportunities for low-grade textile waste to be processed on more localized levels by fashion brands, entrepreneurs or organizations. Future studies are needed in areas that cultivate sustainable models of consumption, design, and production and that help to reform many of the wasteful components of fast fashion.
3. With retail take-back programs growing, further research on the effects of these initiatives for both consumers and brands could offer insights into managing these programs in the future. Additional research could be conducted that compares the textile recycling industry to other recycling industries for a better understanding of consumer behaviors, improving recovery and navigating regulation issues.

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Appendix-A

Unstructured Interview Questions

1. What is your involvement with the issue of apparel and textile waste?
2. What do you think are the key issues concerning textile waste—generation and recovery?
3. What you do think is the best way to reduce and/or handle apparel and textile waste?
4. What do you think are the greatest obstacles that exist for reducing and/or collecting apparel and textile waste?
5. What opportunities do you see that being overlooked in reducing and/or collecting apparel and textile waste?
6. What do you see in the future for handling, managing or reducing textile and apparel waste?
7. Do you think that the disposal and/or collection of textile waste should be regulated by government?
8. Can you share your thoughts and opinions on the current apparel consumption and disposal habits of consumers?
9. What are the costs, financial or otherwise associated with collecting textile waste and diverting it from landfills that you know?
10. Do you support collaborative efforts between stakeholders to increase the recovery of textile waste?
11. How do you think the public can be better educated on this issue to reduce landfill disposal of apparel and textile waste?
12. How can New York State's leadership in this area be a model for other states?
13. If there was one thing that you wanted the public to know about textile waste and recycling, what would it be?
14. If there was one thing you could find out from public consumers regarding textile and waste and recycling, what would it be?

Appendix-B: Information on Environmental Sustainability in Textile wastewater management in India

Sl No.	Content	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
1.	**Labor input in the textile industry**	**1**	**2**	**3**	**4**	**5**
a)	Increase in employee wages					
b)	Difficulty in recruiting general staff					
c)	Low rate of worker retention					
d)	Difficulty in recruiting engineer staff					
2.	**Policy implications**	**1**	**2**	**3**	**4**	**5**
a)	Unstable political and social conditions					
b)	Underdeveloped infrastructure (electric power, transportation, communications, etc.)					
c)	Unclear policy management by the local government					
d)	Complicated tax procedures					
3.	**Dyes and additives**	**1**	**2**	**3**	**4**	**5**
a)	Basic dyes, Mordant dyes and Acid Dyes (Silk, Wool ,Nylon (Ionic bond))					
b)	Direct dyes and Disperse dyes (Cotton, Polyester, Acetate (Ionic bond))					
c)	Vat dyes and Sulphur dyes (Cotton, Cellulose (Dye precipitated in the fibre))					
d)	Azoic dyes and Reactive dyes (Cotton, Cellulose (Covalent binding))					
4.	**Wastewater treatment and disposal**	**1**	**2**	**3**	**4**	**5**
a)	Landfill					
b)	Agricultural use					
c)	Recovery					
d)	Building and construction materials					
5.	**Energy consumption and carbon dioxide emissions**	**1**	**2**	**3**	**4**	**5**
a)	Implementation of a certified Energy-					

Sl No.	Content	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
	Management-System according to ISO 50.001 as requested by public bodies or customers					
b)	Energy footprint of a production order/article regarding the energy consumption in my company					
c)	Post calculation: Comparison of actual and planned costs in order to identify significant deviations					
d)	Establishing Services to support Carbon-Emissions Trading (forecast, sourcing)					
6.	**Textile industry productivity**	**1**	**2**	**3**	**4**	**5**
a)	Regulation influenced technology transfer and R&D activities of your firm					
b)	Has the flow rate of productivity change					
c)	Has you adopt to improve productivity?					
d)	Have you plan to increase the degree of automation of your production					
7.	**Textile reuse and recycling**	**1**	**2**	**3**	**4**	**5**
a)	Reuse (Run your own store)					
b)	Reuse (Sell to non-profits or other businesses)					
c)	Reuse (Sell to a broker)					
d)	Recycling					
8.	**Improvement of sustainability related performance**	**1**	**2**	**3**	**4**	**5**
a)	Sludge disposal efficiency					
b)	Efficiency of sludge treatment					
c)	Weighted average Reagent consumptions					
d)	Sustainable Performance Measurement for textile Wastewater Treatment Plants					

Sl No.	Content	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
9.	**Economic performance**	**1**	**2**	**3**	**4**	**5**
a)	Reduction in costs through improved efficiency of production and sales					
b)	Expand the range of low price products / services					
c)	No measures have been taken					
d)	Increased efficiency through management integration within the group					
10.	**Environmental impact**	**1**	**2**	**3**	**4**	**5**
a)	Stricter environmental regulations					
b)	In your view, has air pollution ever affected your health					
c)	Apart from effects on people's health, are you aware of any other effects of air pollution					
d)	Jobs today are more important than protecting the environment for the future					
11.	**Operational performance**	**1**	**2**	**3**	**4**	**5**
a)	Brand identity is strong and established					
b)	Goodwill is already earned due to old customers in the market					
c)	Old customer relationship and retaining them successfully					
d)	Quality of the fabric is up to the mark					

List of Publications

List of publications in International Journals

1. **Punyasloka Pattnaik**, G. S. Dangayach, Awadhesh Kumar Bhardwaj (2018). A review on the Sustainability of Textile Industries Wastewater with and without Treatment Methodologies. **Reviews on Environmental Health**. 33:163-203. **SCIE**
2. **Punyasloka Pattnaik**, G. S. Dangayach. (2019). Sustainability of Wastewater Management in Textile Sectors: A Conceptual Framework. **Environmental Engineering and Management Journal (EEMJ)** 16(9). **SCIE**
3. **Punyasloka Pattnaik**, G. S. Dangayach. (2019**).** Sustainability of textile waste-water management by using integrated fuzzy AHP-TOPSIS method: A case study. **Int. J. of Environment and Sustainable Development (IJESD)** (Accepted) **SCOPUS & ESCI**
4. **Punyasloka Pattnaik** and G. S. Dangayach. (2019).Analysis of Influencing Factors on Sustainability of Textile Wastewater: A Structural Equation Approach. **Water, Air, & Soil Pollution: An International Journal of Environmental Pollution**. **doi.org/10.1007/s11270-019-4206-x** (**SCI)**

List of publications in International Conferences

1. **Punyasloka Pattnaik**, Govind Sharan Dangayach (2019). Sustainability of Textile wastewater management by using Fuzzy AHP method. **International Conference on Sustainable Computing in Science, Technology and Management (SUSCOM-2019),** Amity University Rajasthan during February 26-28, 2019

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She has published four research papers in International Journals and presented one research paper in International Conference. Since July 2016, she has been engaged in her Doctoral research in the area of sustainability of textile wastewater management at Department of Management Studies, Malaviya National Institute of Technology Jaipur, Rajasthan, India.