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Sustainable Methods for Effluent Treatment of Textile Chemical Processing: A Review

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ABSTRACT

Textile sector provides livelihood from landless labourer, marginal farmers, retailers, small vendors to big industrialist. Share of GDP from textile sector in Indian economy is around 5.14 per cent in 2021. As the demand for eco-friendly, sustainable, anti-microbial clothes and fabric increases, textile industries tend to produce more diversified products with varying properties. More the produce, more will be the resource utilization and in turn residue generation will also increase simultaneously. Textile industries are supposed to generate huge voluminous toxic effluent generated during dry and wet process of yarn or fabric treatment. These effluents consists of carcinogenic dyes and chemicals which not only a threat to living beings but also to the environment. A holistic, novel and scientific methods towards effluent treatment is the need of the hour to tackle this alarming residue. This review is a collective effort towards effluent treatment methods used worldwide till date and different rules and regulation followed by the government towards its discharge.

HIGHLIGHTS

- In world, about 80% of wastewater are discharged into nature without proper treatment.
- In India, only 37.1% of total sewage generation is being treated.
- Major effluent treatment processes are Physical (adsorption, filtration, screening, chromatography, etc.), Chemical (oxidation, ozonation, photo-oxidation, etc.), Biological (microbial degradation, biofilms, bioreactor, phytoremediation, etc.) and Electrical.
- Reduce, reuse and recycle must be followed to achieve safe disposal.

Keywords: Textile, Fabric, Dyes, Effluent Standards, Discharge, Environment

Textile sector is the largest industrial unit dated before the industrial revolution. During 18th century, these sector get the booming stage and still continuing at an enormous pace. India stands at 6th position with respect to textile and apparel exports in the world (MoT, 2020-2021). As the industry gets diversified with different types of products and technology, generation of residue also increases. The major residual part of the textile sector is the solid and liquid as effluent. Effluent is the residue left after dry and wet processing of textile. Mostly, it is voluminous and contains solid fibre along with chemicals used during dry and wet processing. A general flow chart of working processes of textile sectors are represented in Fig. 1.

In the Fig. 1 as we go from initial stage of raw material collection to the final stage of waste disposal, the volume and toxic nature of effluent goes on increasing tremendously until and unless treated. Colour change of each step in the above

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charts gives a general view of toxicity of the effluents present in those respective steps. Toxicity of effluents increases as we start treating with chemicals and one must achieve safe level treating before discharge. In general, the volume of effluent produced in textile sector to produce a unit volume of the product is 200 times higher (Wang *et al.* 2011). It requires huge amount of water at each and every steps. Despite using clean water for textile processing and fabric washing, we are unable to generate clean water as it was and in turn the effluent is generally a mixture of short fibres, toxic dyes and chemicals used during different dry and wet processing, etc. These multi-national industries usually treat this effluent to some extent but still there are many small scale industries and vendors are operating without any sewage or effluent treatment plants. As a result, 47.2% of the effluent generated throughout the world is discharged directly into the nature without any treatment (Ehalt Macedo *et al.* 2021).

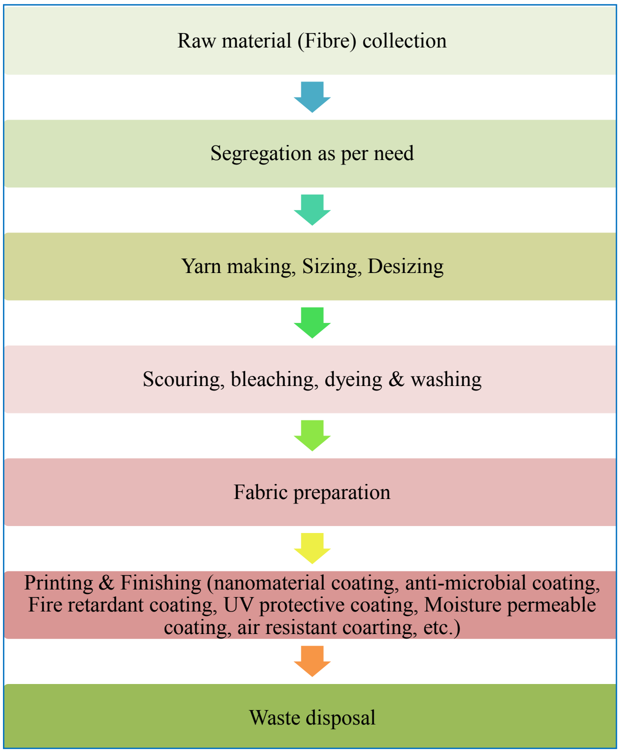

Fig. 1: Representation of dry and wet processes of textile industries

As per United Nations, about 80% of wastewater is discharged into nature without proper treatment (UN, 2020). In 2015, member countries of the Unoited Nations have committed 17 Sustainable Development Goals to be completed by 2030. Under these 17 goals, effluent treatment comes under 6th goals (Clean Water and Sanitation). In India, the capacity of sewage water generation is 72368 MLD (million litre per day) and out of this, 26869 MLD are being treated by operational sewage treatment plants, which accounts to only 37.1 per cent of the total (ENVIS, 2021). For achieving the goal of sustainability, one must go for well planed scientific approach for effluent treatment. Effluents are always complex and heterogeneous in nature. It consists of different types of scouring, degumming, sizing and desizing chemicals, chemicals used for bleaching, chemical dyes, paints, finishing chemicals, etc.

Effluent Treatment Methods in Use

In general, the steps involved for effluent treatment are effluent collection, primary treatment (filtration and screening), secondary treatment (aeration, oxidation, coagulation, flocculation, microbial culture addition for degrading toxic compounds), tertiary treatment (disinfecting with chlorinating agents) and lastly safe disposal. Effluent treatments steps can be summarized by Fig. 2.

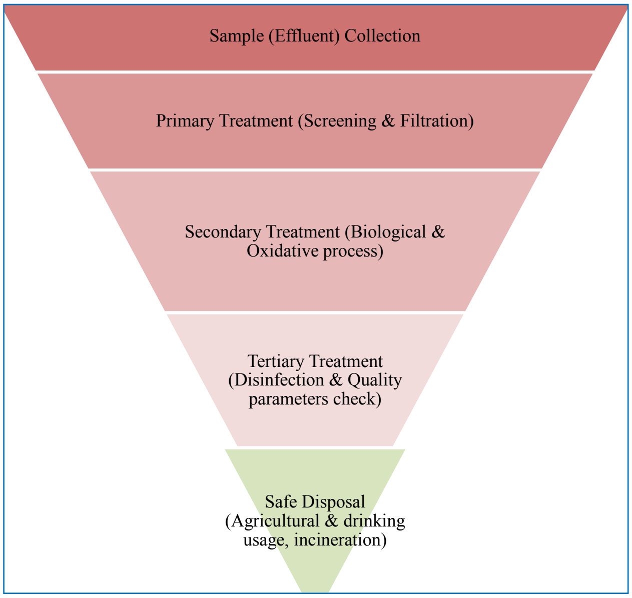

Fig. 2: Schematic representation of effluent treatment steps

1. ***Solid material separation/ Primary treatment:*** During collection of effluent from the source, solid particles and materials are filtered or screened out using mess or net. After separation of solid wastes, effluents are settled in tank for separation of sludge material. Then the effluent is passed to another tank for secondary treatment.

2. ***Secondary treatment:*** Aeration is provided to the tank followed by addition of microbial culture (*Bacillus sp., Pseudomonas sp.*, etc.) for degradation of pollutants and then oxidizing chemicals like $KMnO_4$, strong acids like H_2SO_4, HNO_3, etc. are added to oxidize the toxic material (Vu and Wu, 2020). Once the oxidation is over, the effluents are subjected to coagulation and flocculation by addition of salts multivalent ion (alum, ferric sulphate, polyelectrolyte, etc.). After all the secondary treatments effluents are allowed to settle down in order to remove the precipitated or settled sludge material and the liquid effluents part are charged for tertiary treatment in another tank. In secondary treatment, major detoxification or precipitation takes place.

3. ***Tertiary Treatments:*** This step of treatments involves chlorination (bleaching powder) for disinfecting the disposable effluent and testing different parameters for discharge. Before discharging the effluents to the environments, the quality parameters like pH, BOD, COD, suspended solids, heavy metal concentration and types, microbial counts, etc are checked. In India, as per National Green Tribunal 2019 (NGT), the desirable limits in drinking water for these parameters are pH (5.5-9), BOD_5 (10 mg/L), COD (50 mg/L), suspended solids (20 mg/L), Lead (0.1 mg/L), Arsenic (0.2 mg/L), Mercury (0.01), Cr^{6+} (0.1 mg/L), microbial indicators (<230 FC MPN/100 mL), etc. (Schellenberg *et al.* 2020). These standards vary as per different rules and regulations of the governing countries. Again they vary with respect to use of discharge effluents like whether it is used for agricultural purpose, drinking purpose, etc. The desirable limits for discharge water from textile industry after treatments and disinfection are given in Table 1 (Gronwall and Jonsson, 2017).

Table 1: Desirable limits for discharging effluents from textile industry in India

Effluent parameters	Standards
pH	6.5-8.5
BOD_3 at 27°C	30 mg/L
COD	250 mg/L
Suspended solids	100 mg/L
Oil and grease	10 mg/L
Colour, P.C.U (Platinum Cobalt Units)	150
Total Chromium (as Cr)	2.0 mg/L
Phenolic compounds	1.0 mg/L
Sulphide (as S)	2.0 mg/L
Ammonical Nitrogen (as N)	50 mg/L
Sodium Adsorption Ratio (SAR)	26
Total Dissolved Solids (TDS), inorganics	2100 mg/L

4. ***Safe disposal:*** The liquid effluents are directly discharged into nature or used for drinking or agricultural purposes after achieving all the standard parameters as per different utilization purposes. The solid wastes can be used as an alternative for manures or are dumped at a site provided by authority or are incinerated. This stage is most crucial and is to be monitored strictly and carefully before discharging.

Researchers throughout the world have used different types of techniques and methods to treat the effluent in an eco-friendly and sustainable ways. Some of the commonly used methods are physical, chemical, biological, electrical and hybrid approaches have been found promising (Madhav *et al.* 2018), but still improvements are much needed. Some of the technologies or methods of effluent treatment in use are listed in Table 2.

Table 2: Technologies or methods of effluent treatment in use throughout the world

Effluent Treatment Methods	References
Adsorbents (activated carbon, silicon polymers and kaolin)	Suba *et al.* 2019; Mohamed and Hassabo, 2019; Slatni *et al.* 2020
Membrane filtration (nanofiltraion, ultrafiltration, microfiltration, reverse osmosis, etc.)	Guneş and Gonder, 2021; Santra *et al.* 2020; Huang *et al.* 2019
Biological (biofilm surface oxidation, aerobic & anaerobic biological treatment, phytoremediation)	Mulinari *et al.* 2020; Rathour *et al.* 2021; Samuchiwal *et al.* 2021
Chemical (oxidation, ozonation)	Kaur *et al.* 2019; Zhang *et al.* 2021;
Electrochemical (anode cathode reaction in an electrolytic solution)	Sharma and Simsek, 2019; Rodriguez-Narvaez *et al.* 2021
Photochemical (oxidation on nanopartice surface in light)	Pandian *et al.* 2018; Sathya *et al.* 2021
Physicochemical (Chemical oxidation on surface of filtration membrane)	Agrawal *et al.* 2020; Louhich *et al.* 2019
Photooxidation (in presence of UV light or sunlight)	Dalari *et al.* 2020; Hudaya *et al.* 2016

Physical Methods of Effluent Treatment

These steps generally do not use any chemicals or microbes to detoxify or degrade the effluents. Here, the basic principles followed are adsorption, absorption, selective adsorption or absorption, membrane filtration, ion exchange, or chromatographic techniques, etc. (Rashid *et al.* 2021).

Chemical Methods of Effluent Treatment

These methods usually use chemical properties of compounds to detoxify, degrade or precipitate the effluents. Oxidation, coagulation, flocculation, etc. are mostly used approaches for chemical treatment (Kiran *et al.* 2017). Novel methods of using nanoparticles for removal of dyes from effluents have also been studied by Marimuthu *et al.* (2020).

Biological Methods of Effluent Treatment

Biological treatment utilizes microbes to degrade or remove contaminants present in the effluents. It's a slow process and pH and temperature dependant as living microbes are involved. It may be under aerobic, anaerobic and may use be used as microbial film, suspension or solution. Phyto-remediation is also done to remove the contaminants by the use of exhaustive plants (Mustafa and Hayder, 2021).

Electrical Methods of Effluent Treatment

These methods deploy the use of electric current in anode cathode circuit in effluent solution to precipitate, coagulate or degrade the toxic material or contaminants present in the effluent (Tian *et al.* 2018).

Hybrid Methods of Effluent Treatment

In the hybrid methods, we generally combine the above mentioned methods to obtain the efficient and sustainable approach for effluent treatment. It may be physic-chemical, electro-chemical, photo-chemical or a combination of physical, chemical and biological methods, etc. (Bahri *et al.* 2018; Sathiskumar *et al.* 2018). In these methods chances of achieving highly efficient effluent treatment methods or a combination can be possible.

CONCLUSION

In order to get highly efficient, reliable, cheaper, eco-friendly and sustainable methods of effluent treatment one must go for scientific approach, green chemistry approach, reduction of waste generation at the source, recycling of residual material and reuse of treated or generated waste for some alternative usage. Usage of less toxic and less hazardous chemicals as alternatives to toxic one, highly efficient physical methods and safer biological treatments should always be enhanced and encouraged. These methods can be tried in batches or sequence to get higher efficiency. Governing country must deploy scientific approaches and stricter rules and regulations for effluent treatments and their discharge in order to safe guards the environment and the mother earth.

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