International Journal of Home Science 2023; 9(2): 291-295

International Journal of Home Science

ISSN: 2395-7476
IJHS 2023; 9(2): 291-295

www.homesciencejournal.com
Received: 03-05-2023
Accepted: 08-06-2023

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Clean technologies for textile processing units: Need of the hour

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Abstract
Textile processing is one of the largest industrial users of process water and huge quantities of chemicals at different stages of processing. The unused materials from these processing operations are discharged as wastewater that is high in BOD, COD, pH, and temperature, color, odors, turbidity and toxic chemicals. The direct discharge of this wastewater on water bodies like streams and rivers pollutes the water and affects the flora and fauna. In India, the capacity and the technology of wastewater treatment plants are abysmally poor compared to vast effluents that contribute to water contamination. So, in order to reduce the wastewater problem or for the conservation of energy, materials and other resources, the development of clean technologies is the possible solution that needs to be focused on.

Keywords: Clean technology, waste minimization, recycling

Introduction
"Clean technologies" are defined as "product technologies or manufacturing processes that reduce pollution or waste, energy use or material use in comparison to the technologies that they replace. The textile industry should focus more on these technologies to prevent pollution while conservation of resources in textile processes and minimizing the generation of wastes and emissions through various techniques is termed by different terminologies such as Pollution Prevention (P2), Waste Minimization (WM), Clean Technology (CT), Resource Conservation (RC) etc.

Benefits of clean technology
Clean technology is not a one-time activity. It is an ongoing technology of improvement. With continually evolving technologies, best practices, changes in raw materials, recycling methodologies, changing human attitude, there is always a scope for improvement. Clean technology helps in meeting the environmental challenges better by reducing generation of pollution from any source and quite often with enhanced profitability so it protects the environment degradation, and consumer interest. The other benefits of clean technology include a better work environment, improvement in product quality, and also an Environmentally-friendly image of the industry and even creation of new market opportunities. Thus it improves efficiency, profitability and competitiveness of enterprise in the present global market.

Clean technology puts more emphasis on
- Pollution reduction in textile industry
- Recycling of textile effluents
- Energy saving and
- Resource conservation

Pollution reduction in textile industry
Pollution can be controlled by adoption of some pollution control measures along with certain measures like recovery, reuse, process modification, etc. Some steps in the efficient control of water pollution can be:

Reduction in wastewater volume
This can be achieved by:
- Reducing the number of washing in the sequence and use of hot water in washing.
- Reutilization of wash water from subsequent washings for the previous washings i.e., recycling of less contaminated wash water in the succeeding washing operations and use of low material to liquor ratio systems, whenever possible.

Reduction of waste concentration by recovery and reuse
- Finishing leftovers can be collected and reused for finishing of either the same or other sorts after sufficient adjustment.
- Possibility of reusing spent acids from carbonizing can be explored.

Reduction of waste concentration by chemical substitution
It may be possible to substitute harsh chemicals by soft chemicals and thus reduce pollution load, e.g.
- Use of mineral acid in place of acetic acid (Mineral acids have zero BOD against about 60% BOD of acetic acid).
- Use of synthetic detergents in place of soaps (Synthetic detergents exhibit 0-20% BOD against 140%BOD for soaps).
- Use of eco-friendly chemicals

Reduction of waste concentration by process modification:
By certain modifications in textile processing, the water pollution load can be reduced considerably
- Use of mineral acid in de-sizing, to correct the pH of combined effluent, which is otherwise highly alkaline in nature.
- Partial or complete use of suitable emulsions in printing in place of printing gums which can reduce BOD of effluent.
- Increased use of transfer paper printing to avoid water pollution.

1. Recycling of textile effluents
As the cost of water supplied to industry keeps increasing, recycle schemes become more attractive with good payback periods. Membrane process covers a wide range of separation through the use of different types of membranes. There are four membrane technologies for effective recycling of textile effluent in the textile industry.
- Membrane bioreactor
- Ultrafiltration
- Nano filtration
- Reverse osmosis

Membrane Bio-Reactor (MBR)
In MBR technology, submerged membranes are used in place of clarifiers to separate sludge from the waste water and produce high quality usable water. As the membrane acts as a fine filter, it does not require any further treatment using sand filters, activated carbon filters, etc.

Ultrafiltration (UF)
UF is mainly used as a pretreatment to nanofiltration and reverse osmosis, so UF helps in avoiding nanofiltration/reverse osmosis fouling. UF has the following advantages:
- Increased flux in reverse osmosis
- Reduced cleaning frequencies of reverse osmosis
- Increase life of reverse osmosis. Membrane

Nano Filtration (NF)
NF has a much smaller pore size than UF; hence it can reject many colour causing elements. NF can very effectively separate the dye and concentrate it too; this method of concentration and purification reduces the loss of dyes. When dyes are removed from the concentrated salt solution, they can be reused in the process thereby reducing the pollution load, and also saving water and salt. This method can be economically applied to separate organics, higher valency cations or anions. Thus softening of any aqueous stream is possible by separating out Ca ++ or Mg++ from Na+, Chlorite ion etc.

Reverse Osmosis (RO)
In a reverse osmosis system, the solution is first filtered through a rough filter like sand or active carbon or a dual media filter, etc.; the pH is adjusted and the solution is then filtered through a micro cartridge filter. The pretreated water is then pumped into the RO tank with a high pressure pump. The membrane separates the pollutants in concentrated form in the reject stream and pure water is collected as permeate. The pressure -range for the RO system varies from 10 kg/ cm2 to 65 kg/cm2.

Developments in clean technology
Some of the technologies that have been developed and can be "adopted" by textile industries in various stages of textile processing are as follows:

2. Pad-batch dyeing
This is a cold dyeing method which is most appropriate for cellulose fabrics like cotton and cotton/ polyester blends. Cold pad batch method is an established and reliable process for obtaining very good dyeing results with minimum use of resources.
In this method fabric is saturated with dye paste and passed through a padder that forces and dyes stuff inside the fabric, while simultaneously absorbing excess dye solution. The fabric is then stored or batched on rolls or in boxes and covered with plastic film to prevent evaporation of water or absorption of carbon dioxide from the air. The fabric is then batched for 2 to 12 hours, during which the dyestuff reacts with fibers and penetrates inside the fabric, resulting in even, consistent colour. This method requires reactive dyestuff and alkali that are highly reactive at normal ambient temperature.

Benefits
- No salt or chemical specialty agents are needed in the dye
- Water and energy consumption is low or nonexistent
- Process is applicable to both woven and knit fabrics
- Equipment is simple, flexible and inexpensive
- Reduction in use of dyestuff

The low cost of adopting this technology makes it attractive to-both small and large dye houses.

3. Low bath ratio dyeing
This batch dyeing process uses a lower than standard weight of water per unit weight of fabric or fiber dyed i.e., M: L ratio. Several new types of jet and package dyeing machines offer low bath ratio dyeing, in the range of 1:1, 3:1, 5:1 compared with a typical value of 12:1. Ultra low liquor ratio (ULLR) machines offer the lowest bath ratios. Dyes used in

these machines must have a high degree of solubility, good leveling, and good washing off and very good "the right first time" dye performance.

Benefits
- This method conserves water, energy, dyestuff and auxiliary dye components such as salt.
- It also reduces steam use and air pollution from boilers.

4. Dye bath reuse
Dye bath renovation and reuse has been shown to be an effective method of cost reduction, energy saving and pollution source reduction in textile processing. In this process, exhausted hot day baths are analyzed for residual color content, replenished as necessary, and reused to dye additional batches of fabric. Dye baths can be reused from 5 to 25 times if the process is properly controlled and if the dyes used are appropriate for the fabric to be dyed. Generally acid, basic, direct and disperse dyes are most amenable to reuse, whereas vat, sulphur and reactive dye are least amenable.

Benefits
- Reduced consumption of dyestuffs and auxiliary chemicals.
- Reduced water and energy consumption.
- Reduced effluent volume.

Limitations
If quality standards for finished products are high, dye bath reused is not favored because there is a high risk of shade variation due to fabric impurities and bath impurities.
Reuse also requires advance scheduling, which limits its use for small lots and "just in time" manufacturing.

Bleach bath reuse
Bleach bath reuse can be used in a manner to dye bath reuse with appropriate holding tanks and several equipment are now available that have the necessary holding tanks. The spent bleach bath contains all of the alkali and heat necessary for the next bleaching operation. Peroxide and chelates must be added to reconstitute the bath. Like dye bath reuse, the number of reuse cycles in bleach bath reuse is limited by impurity build up.

Benefits
- Reduced water and energy consumption
- Conservation of chemicals
- Reduced effluent volume

Automated color mix kitchen
Colors are mixed and matched by computer controlled machinery rather than by mill workers. Machinery is also available for dispensing of powder dye or liquid dyes in batch or continuous dyeing houses. Similarly systems are available to improve speed and accuracy in color matching while mixing.

Benefits
- Reduction of human error, spills, leaks and overuse of dyes.
- Shorter runs for continuous dyeing are more economical.
- Suitable for sophisticated dyeing and printing operations.

Transfer printing
In this method dye is printed on a paper substrate, which is laid onto the fabric to be printed. Temperature and pressure are applied to the paper substrate, which transfer the dye to the fabric by sublimation. Most transfer printing is done on polyester or high polyester content blends with disperse dye and less frequently, solvent dyes.

Benefits
- Lower dye consumption.
- Reduction in energy requirements for printing.
- Generation of little to no printing effluent.
- Inexpensive equipment.
- Short runs are easy to manufacture.
- Printing of paper is more efficient.

Limitations
- Limited to volatile dyes.
- Does not work on natural fibers.

Laser engraving of printing screens
Laser engraving is the practice of using laser to engrave, etch or mark objects/screens. Laser engraving allows for direct digital scanning or onscreen designs of prints. This technique avoids the use of photographic processes in screen making for printing. In this technique a computer system is used to drive the movement of the laser head.

Benefits
- Screen quality is improved.
- Screen changes are simple.
- Small lots are easier to manufacture.
- Less water and energy is required.

Counter current washing
This technique is used in multistage washing operations, on the principle that fresh, clean water need not be used for all washing steps, particularly during the early wash stages when the fabric is dirtiest. In counter current washing, clean water is used only during the final wash state. This wash water is circulated for successive reuse in each of the previous stages until reaching the first stage. The countercurrent washing method is relatively straightforward and inexpensive to use in multistage washing processes.

Benefits
- Counter current washing can reduce water usage by 50 to 80%, depending on the throughout and number of washing stages.
- Counter current washing is useful after continuous dyeing, printing, desizing, scouring and bleaching.
- Equipment and machinery are readily available, so counter current washing is widely practiced in the textile industry.

Bio-scouring
The enzymatic process called bio scouring allows cotton to be treated under very mild conditions. In bio scouring alkaline pectinase enzyme is used for natural cellulosic fibres such as cotton, linen, hemp and blends. It removes pectin and other impurities from the cell wall of the cotton fibres. without, degradation of cellulose and thus has no negative effect on strength properties of the fabric, Depending on the type of enzyme the application can be done in machines normally used for textile wet I processing e.g. pad, box, Jiggers and jets. Bio-scouring can also combined with other wet processes such as:

- Desizing and bio-scouring
- Bio-scouring and dyeing
- Bio-scouring and bio-polishing
- Bio-scouring, bio-polishing and dyeing.

Combining these processes offer considerable time, water and energy savings.

Benefits
- Softer cotton textile
- No cellulose/fibre damage
- Less water and energy required
- Less chemicals used
- Environment friendly technology

Ultrasonic assisted dyeing
Ultrasonic waves accelerate the rate of diffusion of the dye inside the fibre with enhanced wetting of fibres. The influence of ultrasonic waves on the dyeing system has threefold effects namely, dispersion effect i.e., breaking up of micelles and high molecular weight aggregates into uniform dispersion in the dye bath, degassing by the removal of dissolved or entrapped gas molecules or air from fibre capillaries and interstices at the crossover points of the fabric into liquid thereby facilitating a dye fibre contact and accelerating the rate of diffusion of the dye inside the fibre by breaking the boundary layers covering the fibre and accelerating the interaction between dye and fibre.

Benefits
- Fibrillation of cotton and rayon.
- Increase rate of dye desorption.
- Does not affect the fastness properties of the dyed fabric.
- Does not affect the strength of the fabric.

Inkjet printing
Ink jet printing is digital technology. In ink jet, liquid ink droplets are ejected from a nozzle under digital control and directed onto surfaces to form images. It is a process of creating prints generated or designed from a computer. The digital printing process can provide an immediate impression of the design as soon as it has been created. The ink jet printers generally use only process ink with fix colorant concentration. Process ink is used to mix all the required shades directly on the substrate. Print: resolution is defined in dots per inch and print speed is defined in characters per second. This technology uses reactive, disperse and-acid dyes.

Benefits
- It is a non-contact and direct printing technology.
- It prints on any surface regardless of its porosity or-absorbency.
- It prints without noise.

Low salt / high fixation dyeing
Use of dyes that require| less salt addition and have a higher degree of fixation compared to the traditional dyes. These dyes are best used with continuous rather than batch dyeing processes, Use of these dyes reduces the quantity of salt and the amount of color contained in dye house effluent and reduces color problems as well.

Surfactants substitutions
Surfactants that are less polluting, exhibit a lower degree of aquatic toxicity should be chosen.

Recovery of synthetic sizes
Synthetic sizes, such as PVA, can be used in place of starch for many textile products. Unlike starch, which degrades during desizing, recovery and reuse of synthetic sizes is technically feasible and is usually accomplished by membrane filtration. Size recovery can be used economically on small streams to remove the size from desizing baths. This process is cost saving and reduces BOD and COD in effluents.

Recovery of caustic soda
Recovery of caustic soda from mercerizing wash water and its reuse after evaporation and concentration saves material costs and reduces waste. One system that avoids the use of caustic (and also water) in the mercerization process is the use of liquid ammonia. This produces the same effect as mercerization without the highly alkaline waste water stream, the ammonia gas is recovered and reused.

Low Add on Finishing
Choosing appropriate machinery and methods that apply a low volume of finish solution to the fabric reduce energy and chemical usage; improve fastness and softness of finished goods.

Use of enzymes and new chemicals
New chemicals are being used in textile processing that is replacing conventional chemicals in order to reduce pollution in the effluent. Various textile processes like desizing, scouring, finishing conventionally use chemicals to obtain the desired effect, which produce a polluted effluent. Now all these processes can be done through the use of enzymes. Currently, there are alternative chemicals that can be substituted for conventional chemicals that would produce a 50% reduction of pollution in the effluent
e.g. Acetic acid can be substituted with Green acid, Soda ash with Green soda etc.

Emerging Technologies
These demands on the quality of effluents and water scarcity have led to new technology and the use of new chemicals. It is for these reasons that water conservation in textile processing will be the driving force in new technology. New technology in textile manufacturing is focused on reducing the amount of water needed to perform processing techniques while maintaining the quality of finish on the product.

Ultrasonic Technology
Ultrasonic waves are being researched in order to replace processes that require water or to decrease the amount of reagents in the effluent. The ultrasonic waves can produce effects on textiles that are similar to current physical and chemical techniques with the advantage of not using water. Instead of chemicals or machinery that requires water during processing, researchers are allowing the fast impulses of the ultrasonic waves to do the work. The waves also increase the dye absorption into a textile product so less dye will be in the effluent at the end of the process.

Foam Technology
In Foam application air replaces water as the transport medium between the reagent and textile. This system does not require water to apply a dye or finish to textiles and less waste is produced when compared to the conventional padding method because not the entire reagent is impregnated into the textile during padding.

- **Direct dye-bath monitoring and control systems:** Control strategy that adjusts the dyeing process in real time to account and correct for uncontrollable parameters.
- **Supercritical fluid dyeing:** Uses Carbon dioxide as the fluid medium on disperse-dyed synthetics, eliminating aqueous effluent and recovering surplus dyes from the system. It is more economical and environment friendly.

Conclusion
Clean technologies are preventive business strategies designed to conserve resources, mitigate risks to humans and the environment, and promote greater overall efficiency through improved production techniques and technologies. It also improves profitability and competitiveness of enterprises in the present global market.

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