Muhammed Alamgir, S.M. Tariqul Islam and J. A. Saju (Eds.)
ISBN: 978-984-35-4034-8

Full Paper of the WasteSafe 2023 –8th International Conference on
Integrated Solid Waste & Faecal Sludge Management
25-26 February 2023, Khulna, Bangladesh

WASTEWATER RECYCLING OF A BANGLADESHI DENIM FACTORY: A CASE STUDY

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ABSTRACT

The textile industries of Bangladesh rely heavily on groundwater resources to meet manufacturing and domestic needs. Locally, approximately 1,500 billion m^3 of groundwater is extracted annually for textile process operations, and within the country, groundwater in areas with high concentrations of textiles is lowering at a rate of 2.0 – 3.0 m/ year. In 2021, around 349.0 million m^3 of wastewater was produced from textile industries, resulting in the pollution of freshwater resources and posing public health hazards. To reduce the pollution load and dependency on groundwater resources, recycling and reusing wastewater appear to be the primary solution. The current study analyzed the suitability of using treated wastewater in the manufacturing process of a denim textile industry in Bangladesh. The fabric quality results of the dyed and washed denim samples with treated water and wastewater showed promising results for recycling and reusing the treated effluent back in the wet processing unit.

INTRODUCTION

Over the past several decades, the textile sector of Bangladesh has been a huge contributor to the economic growth of the country (Hasan et al., 2016). This sector contributes more than 80% of the export earnings to the country's economy and holds a share of roughly 12.3% in the national gross domestic product (GDP) with an annual income of 28.0 billion USD in the Fiscal Year 2017-18 (Mia and Akter, 2019; Hossain et al., 2018). There are over 7,000 operational industries in Bangladesh that employ more than 4.0 million people (Mia and Akter, 2019; Masum, 2016). The textile sector mainly produces ready-made garments (RMG), woven, and knitwear for different international brands from North America and Europe (Hasan et al., 2019). Past researchers found that the manufacturing process of the Bangladeshi textile industry has the highest ecological footprint due to its high consumption of water, energy, and chemicals that are used in the dyeing, washing, and finishing processes of textiles (Hasan and Leonas, 2018).

Textile production processes such as dyeing, washing, finishing, desizing, scouring, and bleaching are heavily water-dependent (Masum, 2016; Mia and Akter, 2019; Haque et al., 2021). The source of water supply for most of the textile factories is groundwater that is extracted from industry-based private deep tube wells. The groundwater consumption is approximately 1500 million m^3 for the textile sector of Bangladesh, which spends around 4.0 billion USD and 980 million kWh of electricity to extract this amount of groundwater (Haque et al., 2021). With an increase in demand for clean fresh water for the growing urban population and industrial activities, the groundwater level within the areas where most of the textiles are located records a drop of water level from the ground surface by 2.0 - 3.0 m per year (Islam and Islam, 2017), and by 2030 this depletion rate is projected to reach 5.10 m/year (Haque et al., 2021).

In the Bangladeshi textile industry, around 80% of the consumed water is used for wet processing (i.e., dyeing, washing, and finishing) facilities, which eventually ends up as wastewater (Foysal, 2022). The typical composition of the wastewater discharged from these textile industries consists of oil, grease, caustic soda, Glauber salt, ammonia, sulfide, lead, and other heavy metals (Muthukumarana et al., 2018). Salts account for around 50% of the discharged textile effluent, which contributes to the elevated levels of dissolved solids, and contributes to the biological oxygen demand (BOD) and chemical oxygen demand (COD). Dyeing chemicals such as hydrolyzed Reactive Blue-19 are toxic, carcinogenic, and/or mutagenic to life forms due to the containment of compounds such as benzidine, naphthalene, and other aromatic elements. Moreover, soda ash, acid, softeners, enzymes, soaping

agents, and peroxides are typically released chemicals within the wastewater of Bangladeshi textiles (Foysal, 2022).

Estimation suggests that the Bangladeshi textile industries have produced 349.0 million m^3 of wastewater by manufacturing approximately 2.9 million tonnes of fabric in 2021, which contained about 1,469,641 tonnes of TDS, 49,442 tonnes of TSS, 175,252 tonnes of BOD, and 519,342 tonnes of COD (Hossain et al., 2018). High levels of wastewater alter the physical, chemical, and biological properties ™of the aquatic environment and pose a serious threat to public health, livestock, wildlife, fish, and other living organisms (Sultana et al., 2009; Islam et al., 2012). In Bangladesh, 20% of freshwater pollution is responsible for fabric processing and dyeing due to the release of untreated and/or partially treated effluents from the garment production process (Haque and ENRAC Team 2017). Additionally, large quantities of wastewater and effluent sludge is produced by the denim-washing factories in Bangladesh (Selim, 2018). It is reported that 2000 million pairs of jeans consume 1.70 million tonnes of different chemicals and 11.4 million m^3 of freshwater resources (Greenpeace, 2016). Reports identified that 80% of the discharged wastewater and other effluent byproducts is causing corrosion in sewer lines, groundwater contamination, surface water pollution, and environmental and health hazards in the areas surrounding the industries (Shamsuzzaman et al., 2021; Sakamoto et al., 2019; Periyasamy et al., 2017).

The present study evaluates the feasibility of reusing treated wastewater in the wet processing plant of a denim facility located in Bangladesh. With this regard, the main objective of the current study is to determine the suitability of recycled wastewater in the manufacturing of denim jeans and evaluate how it can bring water efficiency within the studied facility.

MATERIALS AND METHODS

General Description of the Studied Industry

The denim manufacturing factory selected for this study is located in the Administrative District of Manikganj (Figure 1). Manikganj is located at 23.8617° N latitude and 90.0003° E longitude, which is approximately 55.0 km west of Dhaka city. The studied industry is a ready-made garment manufacturer with a washing facility. Established in 2004, this factory operates within a built-up area of approximately 97,000 m^2, consists of 4 factory buildings, and has received Leadership in Energy and Environmental Design (LEED-Platinum) certification. The factory has the capacity to produce 70,000 denim products on a daily basis. The wastewater generated by the denim factory is equal to the amount of water that is required for use. Table 1 provides the total daily water requirement of the studied denim factory. In comparison to the key performance indicator (KPI) analysis of water consumption to manufacture per unit of fabric, the studied industry has the lowest value in comparison to other RMG factories in Bangladesh as shown by Hossain et al. (2018).

Table 1 Water KPI analysis and daily water requirement of the studied industry

Considerations	Units	Values
Weight of a denim product piece	kg	0.40
Total pieces manufactured per day	pieces/ day	70,000
Total weight of 70,00 pieces	kg	28,000
Water requirement per kg of product	L	73
Total daily water requirement	L/day	2,044,000

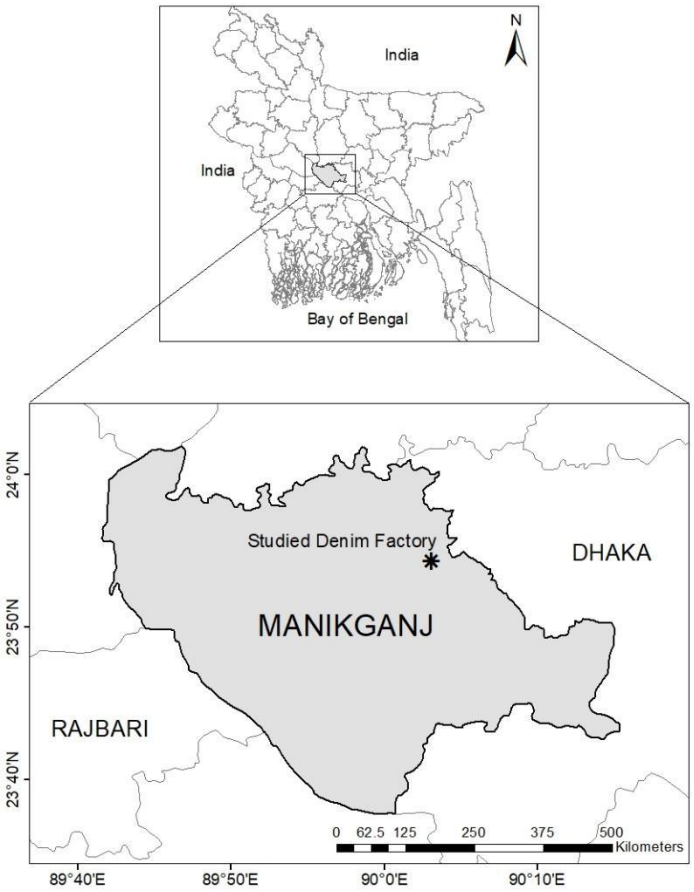

Figure 1 Map of the studied denim textile industry

Groundwater is the main source of the manufacturing and domestic water demands of the industry. The factory uses 70% of the extracted groundwater for manufacturing purposes, and the remaining 30% is used for domestic purposes. Initially, the extracted groundwater is treated with a water treatment plant (WTP) prior to its use within the manufacturing units. Between 60-65% of the treated groundwater is consumed in the wet processing unit of the factory. In the wet processing unit, water is utilized primarily for dyeing, washing, printing, and final finishing of the desired products.

Wastewater Treatment

The factory has a wastewater treatment plant (WWTP), which processes all wastewater that exits after each water-dependent step in the wet processing unit. The WWTP is a biological effluent treatment plant (ETP) that operates at 170m^3/hr for 20 hours a day. Figure 2 shows the process flow of how the wastewater from the factory is processed through the biological ETP and then discharged. The WWTP uses an activated sludge process. The activated sludge process is typically used in biological treatment plants that process wastewater. The microorganisms present in the system break down the complex organic substances present in the wastewater into simple stable substances; as a result, they remove the soluble and suspended organic matter present within the effluent (Lampinen et al., 2001). An activated sludge floc forms because the microorganisms grow a living culture as they digest the organic matter in the presence of dissolved oxygen and multiply in number (Lampinen et al., 2001). The aeration process takes place in the aeration tank present in the system, where the wastewater is mixed continuously with activated sludge and oxygen. The mixture then passes into a clarifier tank, where the settled sludge is separated from the wastewater, accumulated, and returned to be utilized during aeration once again. The wastewater then undergoes microfiltration for further removal of particles. The treated wastewater is then discharged into the nearby water channel.

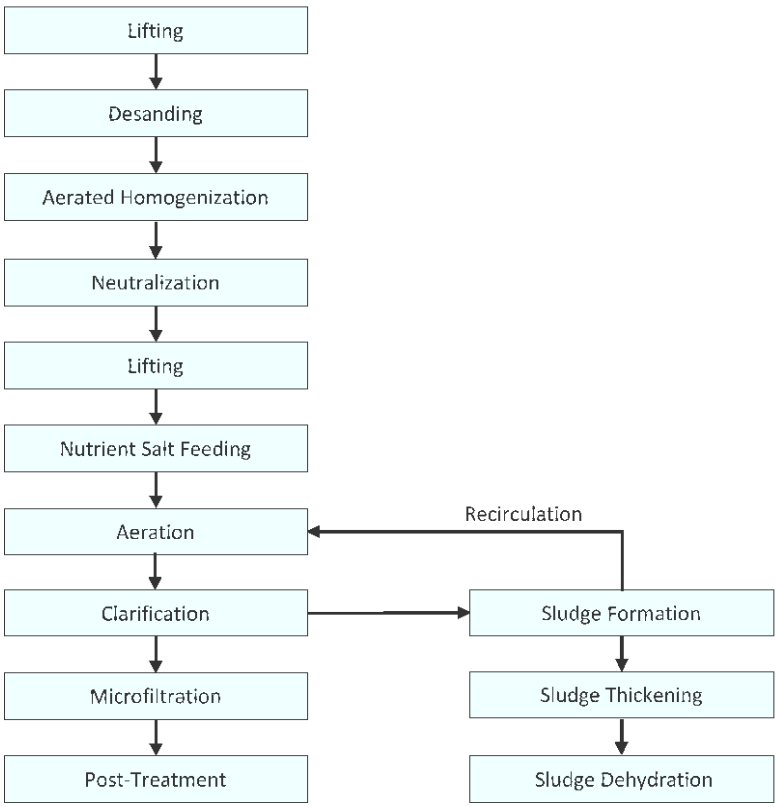

Figure 2 Process flow diagram of the studied industry's ETP

Wastewater Sampling and Reuse

Initially, an assessment was carried out to see if wastewater could be reused in any of the steps of the denim manufacturing process. In this regard, water samples were collected and tested from three different sources – groundwater, ETP inlet, and ETP outlet - of the factory. These samples were tested for the parameters, including pH, total dissolved solids (TDS), total suspended solids (TSS), COD, BOD, total hardness (as $CaCO_3$), Chloride (Cl), and Manganese (Mn), and compared with the values permitted by the Environmental Conservation Rules, 1997. This study evaluates the feasibility of reusing this treated wastewater in the wet processing unit by dyeing and washing the dyed denim jeans that are produced in the factory.

For the feasibility assessment of wastewater reuse in the wet processing unit, a total of 10 sample denim white pants were used. Five samples of denim pants were washed and dyed using the conventionally treated 100% groundwater from WTP, and 5 denim pant samples were washed and dyed using 100% treated wastewater from the ETP outlet. The Turkish Industrial dyeing and washing machine, Yilmak HBM 575, was employed for the dyeing and washing procedures were from. The total dyeing and washing cycle took place at 50°C for 17 minutes. During that time, detergent was added, and the denim pants were washed for 7 minutes and then rinsed. Glauber salt was then added, and the pants were tumbled for 5 minutes. Subsequently, the reactive dye was added to the machine, and the pants were tumbled for 5 minutes and finally dried. Later, the 10 samples were tested for 3 important fabric parameters: (i) Color Fastness (CF) to Rubbing (Dry), (ii) Color Fastness (CF) to Rubbing (Wet), and (iii) Tear Strength, and compared with the requirements of European and North American clothing brands that source denim products from Bangladesh. The methods used for testing the water samples and fabric quality parameters are presented in Tables 2 and 3.

RESULTS AND DISCUSSION

Initially, the ETP outlet and process water that is extracted from the groundwater sources of the Denim facility were used for the feasibility assessment of wastewater reuse. The water samples collected from these two different points of the factory were tested for 8 different water parameters, and the obtained results are shown in Table 2.

ISBN: 978-984-35-4034-8

Table 2 Results of the tested water quality parameters

Sl. No.	Parameters	Source of Water		Discharge into Inland Water (ECR 1997)	Method of Analysis
		Groundwater	ETP Outlet		
1	pH	6.48	7.57	6.0-9.0	USEPA 150.1; SM 4500-H+ B
2	TDS (mg/L)	388	1927	<2100	USEPA 160.2; SM 2540 B - D
3	TSS (mg/L)	9	28	<150	USEPA 160.2; SM 2540 B - D
4	COD (mg/L)	12	120	<200	USEPA 410.4; SM 5220 D
5	BOD_5 (mg/L)	0.8	87.5	<50	USEPA 405.1; SM 5210 B; SM 5210 D
6	Hardness (as CaCO3) (mg/L)	218	460	-	USEPA 130.2.; SM 2340 C
7	Cl (mg/L)	36	540	<600	USEPA 325.6; SM 4500-Cl-
8	Mn (mg/L)	3.80	3.96	<5	USEPA 200.9; SM 3111 B

The extracted groundwater is slightly acidic however the pH value increases in the wet processing unit and after exiting the ETP outlet and remains circumneutral throughout all points of testing. The findings indicate that the concentrations of all tested parameters increase and the most noticeable upsurges are observed in the concentrations of TDS, TSS, COD, BOD_5, and Cl from groundwater to the ETP inlet. This increase is likely due to added detergents, Glauber salts, dyes, and other chemicals used throughout the wet processing of the denim fabric. Moreover, the concentration of TDS, $CaCO_3$, and Cl^- are elevated in the ETP outlet as more chemicals are added to the wastewater before it enters the ETP for treatment, and the formation of sludge increases the TDS of the water exiting the ETP outlet. This treated wastewater, which exits the ETP outlet, meets all the requirements of The Environment Conservation Rules (ECR), 1997 standards for discharge into inland waters, so the wastewater is suitable to be discharged into the government-maintained channel for wastewater.

The test results of the fabric quality for the tested denim samples are presented in Table 3. The table includes here a comparison of the North American and European brands, that source products from the denim industries of Bangladesh. Further, the difference between the tested denim samples that were washed with 100% treated groundwater and the samples washed with treated wastewater is also presented in Table 3. For instance, both samples exceeded the standards of European and North American Brands with regard to the color fastness to the rubbing (dry) test. For color fastness to rubbing (wet), both denim samples exhibit similar results, which did not fulfill the North American standard nonetheless is acceptable for the European brand since it has no requirement for this particular parameter. Tear strength has been tested for warp and weft. Values for warp tear strength using groundwater are 28.95 N and 29.96 for recycled wastewater, whereas the values for weft using groundwater are 14.34 N and 13.64 N for recycled wastewater. This shows that tear strength values are not significantly affected if recycled wastewater is used in the washing and dyeing of denim. All tear strength values satisfy the European brand's standard of being greater than 15.0 N and are acceptable by the North American brand, as it depends on the requirement.

Since the tested fabric quality results show that the denim samples washed and dyed using 100% treated groundwater and recycled wastewater meet the requirements of the principal brands buying products from Bangladesh, there is scope to increase the amount of recycled wastewater usage for production purposes. Therefore, a significant decrease in the dependence on groundwater extraction as well as the amount of wastewater discharge into the nearby government-maintained channels can be achieved.

Table 3 Tested parameters of the denim samples and comparison with two major brand requirements

Test Name	Standard Method	Dyed and Washed Denim Samples		European Brand	North American Brand
		Treated Groundwater	Recycled Wastewater	Required Value	Required Value
CF To Rubbing (Dry)	ISO-105 X12	4	4.0 – 5.0	2.0 – 3.0	3.5
CF To Rubbing (Wet)	ISO-105 X12	3.0 – 4.0	4.0	-	2.0
Tear Strength	ISO-13937-2	Warp=28.95 N Weft=14.34 N	Warp=26.96 N Weft=13.64 N	>15.0 N	As required

Note: N – newton.

CONCLUSION

Due to the usage of different chemicals, the higher capital cost of operating ETPs, and a lack of enforcement of rules and regulations, a substantial amount of untreated and/or partially treated wastewater is released from the textile facilities of Bangladesh. Consequently, impacts on freshwater resources, agricultural activities, as well as other environmental and health issues are growing concerns in the areas with high concentrations of textile facilities. Moreover, heavy reliance on groundwater resources for water supply is threatening future water availability in these areas. As the major portion of the extracted groundwater is utilized in the manufacturing process, efficient water usage can be achieved through recycling and reusing the treated wastewater in the production process of the textile industries.

The present study analyzed the feasibility of utilizing treated effluent in the wet processing unit of a Bangladeshi denim industry. The obtained fabric quality results of the analyzed denim products showed promising values for reusing the treated effluent from the ETP back in the wet processing unit. The findings address Sustainable Development Goal 6.3, which aims at improving the water quality by reducing pollution, eliminating dumping, and minimizing the release of hazardous chemicals and materials, halving the proportion of untreated wastewater, and substantially increasing recycling and safe reuse. Furthermore, the study is an evidence-based response to integrating recycling and reuse approaches for the textile effluent in the Bangladeshi textiles' manufacturing process.

ACKNOWLEDGMENTS

The authors sincerely thank North South University for supporting the study by providing funding under grant no. CTRG-21-SEPS-02. The authors gratefully acknowledge the research support provided by Mr. Mahbubur Rahman and the field assistance of M. S. Rafiq, F. A. Mim, M. Z. A. As-salek, and S. S. Wriddhi.

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