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Innovative use of brick waste for eco-friendly treatment of indigo dye house wastewater: An approach towards waste to resource

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K E Y W O R D S

Brick Waste

Circular Economy

Construction Waste

Indigo Dye

Textile Wastewater

A B S T R A C T

The textile industry is the backbone of Pakistan’s economy, holding a share of 57% in total exports of Pakistan but also possessing several environmental challenges due to the discharge of highly contaminated wastewater. On the other hand, construction and demolition waste is another threat to the environment because of its massive quantity and large area requirement for its disposal. This study explores the use of waste bricks as a sustainable medium to treat textile wastewater. Waste bricks, sourced from construction debris in Hyderabad, were crushed, cleaned, and used in the treatment system. Composite samples of textile effluent were collected from a textile factory in Nooriabad, Sindh, and treated in a brick column treatment system over 14 days. Key parameters such as pH, turbidity, total dissolved solids (TDS), total suspended solids (TSS), hardness, chloride concentration, chemical oxygen demand (COD), dye concentration, electrical conductivity (EC), and total solids (TS) were monitored using standard methods. The results revealed that the waste brick filtration system effectively reduced various pollutants within four2 days and improved further, with significant decreases in COD (94%), dye concentration (99%) , and turbidity (91%) after 14 days, indicating that waste bricks can be a green alternative for wastewater treatment, promoting the concept of “using waste to treat waste” and contributing to environmental sustainability.

1. Introduction

Pakistan's economy is heavily reliant on the textile industry which has a key share in exports of Pakistan, which is about 57%. This industry is considered as one of the key pillars, and its importance for Pakistan's economy is undeniable. Taking advantage of the high global demand for textiles, Pakistan earns significant foreign exchange through the export of textile products in more than 65 international markets [1]. Pakistan has now become the 8th largest exporter of textile products in Asia, capturing a significant shear from the 1.2 trillion U.S. dollar market [2].

Although the textile industry's importance to Pakistan's economy is undeniable, the environmental impact caused by this industry is concerning. This industry is the largest liquid waste-producing industry in the world and requires a huge volume of about 200 L water per kilogram of the finished fabric, Out of which 20 – 50 % comes out as waste [3]. Much of this wastewater is released untreated into nearby sewers, drains, and other water bodies [1]. Water pollution is one of the major environmental concerns of the time and the textile industry is one of the largest contributors to this menace [4].

The effluent from these industries contains several harmful substances that are toxic, teratogenic, mutagenic, and carcinogenic in nature. These pollutants include various types of dyes, heavy metals, and different types of solids which cause high chemical and biological oxygen demands resulting in the deterioration of surface and groundwater resources[5]. This untreated discharge into natural water bodies presents a severe challenge to both humankind and the environment and becoming a threat to aquatic life. Exposure to these pollutants leads to various dermatological, pulmonary, and ophthalmological diseases in human beings [6].

As a developing country with limited resources, Pakistan faces significant concerns in addressing and mitigating these issues. Though environmental protection remains a priority, conventional wastewater treatment facilities are costly and require a high amount of energy and other resources such as land and chemicals [7-12]. In the future, management of overwhelming water quantities with the existing wastewater treatment infrastructure will be confronting. Thus, there is a need to discover a green technology to target this menace without lumbering the economy and it will significantly contribute to the circular economy [13]. Eventually, water with relatively better quality will be obtained which can be reused in other water circuits such as agriculture [14].

In addition to the textile industry, the construction industry also puts a substantial challenge for waste managers specifically in underdeveloped countries like Pakistan [15]. The construction industry is considered the backbone of many developing countries and has an important role in the development of a country. For Pakistan, the construction industry alone shares approximately 2.3% of the GDP of Pakistan [16], but it is also a significant contributor of solid waste and accounts for a substantial share of about 30% of the total solid waste in the world. Reports specify that Pakistan produces about 48.5 million tons of solid waste in a year among which 14 million tons is shared by the construction waste [17]. Similarly, another study reports further aggravated figures and reports this share for about 25% to 40% of total waste and highlights its proper disposal and treatment is a peril for the managers [16]. Construction and demolition waste is difficult to reuse due to its large degree of heterogeneity which not only utilizes a huge area but also brings pollution risk to the ecological environment [18].

Construction waste consists of materials that include bricks, tiles, wood, steel, mortar, and concrete blocks with waste bricks making up a substantial portion [19]. In some estimates, bricks and concrete blocks constitute 30% to 50% of total construction waste, while in Pakistan, the average proportion of waste bricks is around 6%. [11, 16, 17, 19]. Research has shown that the special composition of bricks which contains high contents of silica, alumina, lime, and various metals, is efficient enough to remove various pollutants from wastewater [20]. Furthermore, large specific area, high surface roughness, and multi-channel pores are the additional parameters that make brick a good choice for the removal of various pollutants from effluent [11].

Thus, the use of waste bricks as filter media will lead to promoting the concept of “using waste to treat waste” by making it a sustainable choice for wastewater treatment. Keeping in view the high production of construction and demolition waste and textile wastewater a sustainable, efficient, and low-cost treatment process can be configured in which waste bricks are used for the removal of pollutants from the effluent [21]. This can enhance water recycling by 50% and environmental implications can be reduced by 33% [22].

2. Methodology

2.1 Materials and Equipment

- Waste bricks sourced from construction waste at a site in Hyderabad.
- Composite samples of denim effluent collected from a textile factory in Nooriabad, Sindh, Pakistan.
- Scrap Dispenser bottle (9 inches in diameter, 14 inches in height).
- Malmal fabric (used as a filtration aid at the bottom of the container).
- Filtered water for washing the brick pieces.
- Standard laboratory equipment for testing pH, turbidity, hardness, chloride concentration, COD, dye concentration, TDS, TSS, EC, and TS.

2.2 Preparation of Waste Brick Media

Waste bricks were collected from the construction site and crushed with a hammer into pieces no larger than 2 inches in diameter and were analysed for size distribution through sieve analysis as shown in Table 1. The crushed brick pieces were washed repeatedly with tap water to ensure the removal of dirt and fine particles until the discharged water appeared clean and clear, as per the method suggested by [20].

Table 1

Particle size distribution of the crushed bricks

Sieve Size	Cumulative Retained (%)	Cumulative Passing (%)
2 in	0	100
1-1/2 in	27	73
1 in	59	41
3/4 in	78	22
1/2 in	92	8
3/8 in	98	2

2.3 Experimental Setup and Testing

This methodology follows a systematic approach to evaluate the potential of recycled waste bricks in treating textile denim wastewater, with special attention to key parameters influencing water quality. The treatment process was carried out in an old dispenser bottle measuring 9 inches in diameter and 14 inches in height. The container was cut from the top to provide an opening at the top for the intrusion of brick waste media and at the bottom for the collection of treated water. The unsorted crushed brick pieces were arranged within the container upto a height of 12 in from the bottom, as suggested by [18]. A piece of malmal fabric was placed at the inlet of the bottom opening to prevent blockages during the filtration process. The picture of the developed treatment system is shown in Fig 1. The sample of denim effluent was placed in the constructed waste brick column for treatment. Which was filtered through the column in a batch process. The study was continued for 14 days in the same reactor and samples were collected at regular intervals to monitor the system's efficiency. Water parameters including pH, turbidity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), chloride concentration, hardness, Chemical Oxygen Demand (COD), dye concentration, and Total Solids (TS) were measured using standard methods specified by the American Public Health Association [23]. Temporal variations in all parameters were observed over the 14 days to analyze the filtration efficiency of the developed brick column system. To analyse the effect of material on water properties, a similar study was conducted on deionized water and was placed over the same media for 10 days. The results were evaluated to understand the interaction between the waste brick filtration media and various effluent contaminants.

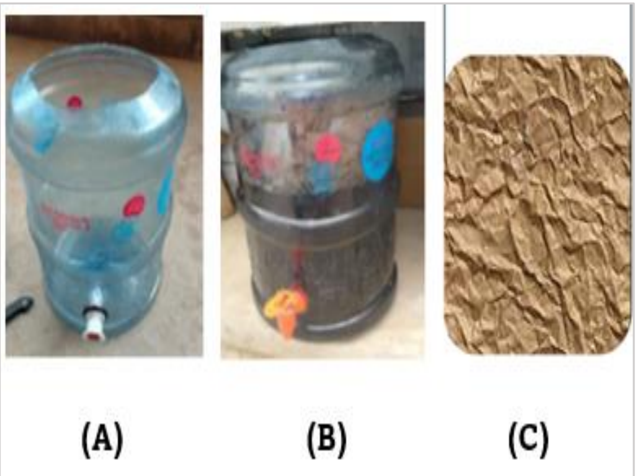

Fig. 1. Representation Of The Developed Filtration System (A) Before Filling The Medium (B) After Filling The Medium (C) Graphical Layout

3. Results and Discussion

The results of the developed treatment system show a complex interrelationship between various parameters. The pH values drop initially and then become neutral after some time interval, this may be caused by intricate interactions among dissolved minerals of the bricks and organic pollutants. Furthermore, the turbidity of the sample is significantly reduced, which is obvious as the media acts as a filter and traps various suspended particles resulting in a decrease in turbidity and TSS. Additionally, the porous structure, high filtering efficiency, and possible microbial development promotion of the bricks all work together to reduce COD and dye concentration, proving the waste brick filtration system's effectiveness in treating a range of wastewater contaminants. These interactions highlight the nature of waste brick filtration for textile denim wastewater and highlight how important the composition of the bricks and particular aspects of the wastewater are in determining the observed results. Table 2 presents the variation of properties of deionized water when placed in the brick media for ten days.

Table 2

Parameters of deionized water after 10 days in the system

Parameter	Initial Value	Final Value
pH	7.0	5.9
TDS (mg/L)	02	273
Turbidity	0	05
Chloride concentration	0	80

The detailed discussion on each parameter and its trend with time is discussed in the subsequent sections. The visual appearance of the samples with respect to time can be visualized in Fig 2.

Fig. 2. Representation Of The Sample From Day Zero To Day 7 (Left To Right)

3.1 pH

The pH of the samples initially decreases towards acidic then it becomes constant in three days. These values varied between 9.07 to 7.03 on the first and subsequent days. This is because water contained certain dissolved minerals like dyes, hydrosulfites, and other heavy metals that could have reacted with the bricks to lower the pH. However, a specific study needs to be conducted to explore this reason further which can elaborate the chemical reactions that took place. Organic contaminants present in the water could release organic acids into the water, causing a decrease in pH, however, this phenomenon has not been studied in this work. The variation in pH with time of the samples is presented in Fig 3.

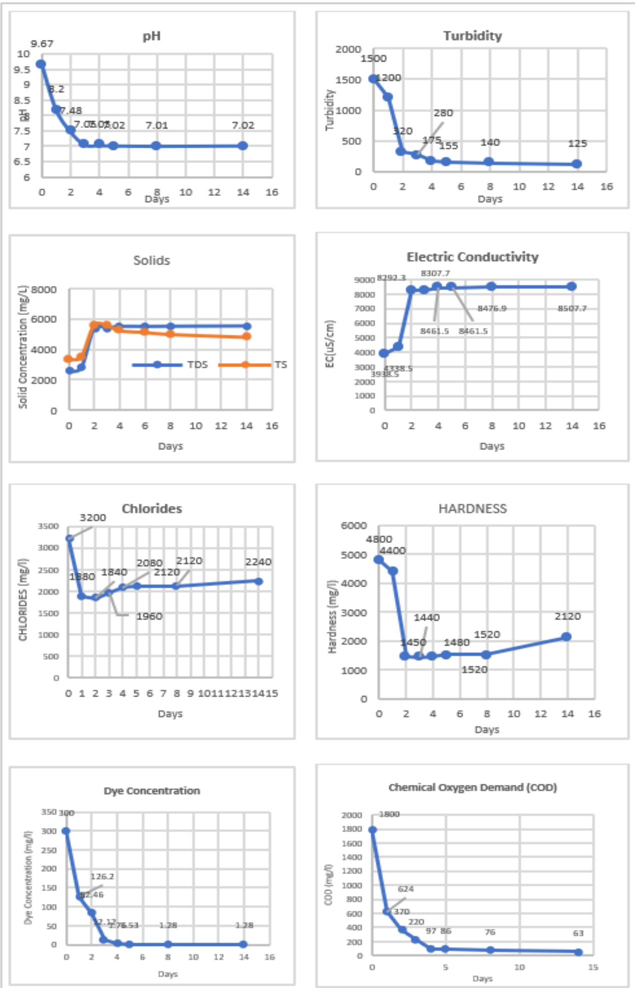

Fig. 3. Temporal Variation In Values Of Various Parameters

3.2 Turbidity

The turbidity values of the sample consistently decreased over time from 1500 to 125 JTU. This decrease was abrupt in the initial 2 days, after 4 days the sample observed a significant reduction in the turbidity whereas after the 4th day, the turbidity value of the sample remained approximately constant at around 140 JTU. This occurs due to several processes, such as the porous structure of the waste brick filter mechanically trapping suspended particles. Additionally, clay minerals in the bricks may also promote flocculation and coagulation, leading to the settlement of various suspended particles resulting in reduced turbidity [24]. The trend of turbidity reduction over time for the developed system is presented in Fig 3.

3.3. Solids

An interesting trend for the solids has been observed, initially, the system shows a reduction in suspended solids, and the trend is continued with time. However, as the filter becomes clogged, its capacity to absorb more particles decreases resulting in low removal of dissolved solids, which is a complex phenomenon. Since the bricks may contain soluble compounds or minerals that are released into the wastewater, especially during the initial contact stages, leaching from the bricks is a significant contribution. The wastewater and brick composition can interact chemically to create new compounds, some of which may be soluble and increase TDS. Additionally, although the solid waste particles are initially captured by the bricks, over time, these materials may slowly dissolve back into the water, increasing TDS levels [25]. The results indicate that the dissolved solids concentration was increased from 2560 to 5530 mg/L, whereas, the total solids initially increased from 3340 to 5620 mg/L and then subsequently reduced to 4815 mg/L in 14 days. The trend of total solids and dissolved solids over time in the sample is presented in Fig 3.

3.4 Electrical Conductivity (EC)

A similar trend is observed for the values of EC with time. The EC values in the system initially increase from 3938 to 8300 uS/cm, whereas after two days they become almost stable at around 8400 uS/cm, indicating a constant EC. This is due to the concentration of ions and dissolved salts in wastewater having a significant impact on its electrical conductivity (EC). The initial Rise in the EC indicates that the water has more ions and salts dissolved in it. The increase in EC is because of the increase in the quantity of ions that are available to conduct The EC of the treated water is likely to raise the waste bricks chunks contribute to leaching or other activities that add ions or salts to the water (raising the TDS). Fig 3. further illustrates the trend of EC values over time in the sample.

3.5 Chloride Concentration

Contrarily, the chloride level initially decreased from 3200 to 1840 mg/L as the bricks absorb chloride ions. This is because the bricks initially function as efficient adsorption material, removing chloride ions from influent wastewater. However, as the filtration process continues and adsorption sites become saturated, desorption occurs, leading to an increase in chloride concentrations to 2240 mg/L after 14 days. This reflects the saturation and eventual release of previously adsorbed ions [26]. The trend of chloride concentration over time is presented in Fig 3.

3.6 Hardness

In the same way, hardness values initially decreased from 4800 to 1440 mg/L, as calcium and magnesium ions are adsorbed by the bricks, however, as saturation occurs, these ions are released back into the water, causing hardness to increase again reaching to the value of 2120mg/L in 14 days. This trend is linked to the overall rise in TDS, reflecting a balance between adsorption and desorption processes [27]. Variation in hardness values is presented in Fig 3.

3.7 Dye Concentration

Indigo Dye concentration has been observed with a decreasing trend over time and decreased from 300 to 1.28 mg/L, this is due to the porous nature of the bricks, which trap dye molecules through surface adsorption. The dye may change or degrade as a result of chemical reactions between the brick's elements and pollutants in the wastewater, however, as adsorption sites become saturated, the system's efficiency declines, though physical filtration and sedimentation also contribute to dye removal. The porous structure of the bricks effectively captures dye particles, reducing the dye load in wastewater. Furthermore, the filtration procedure encourages dye particle sedimentation, which helps to remove the particles from the water. These relationships are intricate, which emphasizes how well waste brick filtering works to lower the amount of dye in wastewater from textile and denim production. A similar study was conducted on the removal of dyes from industrial effluents using burnt brick and the results were significant for the removal of dyes due to the adsorption characteristics and porous nature of the burnt brick [28]. The trend of dye removal over time can be visualized in Fig 3.

3.8 Chemical Oxygen Demand (COD)

A similar decreasing trend for COD is also observed, that decreased from 1800 to 63 mg/L, this decrease was abrupt in the initial four days followed by a steady decrease for the remaining observation period. This phenomenon is due to the adsorption of organic contaminants by the bricks and potential microbial activity within the filter, which promotes biodegradation. Chemical interactions between the bricks and wastewater further reduced COD, demonstrating the system's efficiency in treating organic pollutants. Dires et al [29] have attributed this efficiency to the porous surface structure of the bricks. Fig. 3 shows the COD removal trend over time through the developed system.

In summary, the waste brick filtration system presents complex interactions across multiple parameters. Initial drops in pH, turbidity, and TSS reflect the bricks' adsorption capacity while rising TDS and chloride levels indicate saturation and desorption. EC correlates closely with TDS, while hardness trends mirror those of dissolved solids. The system's effectiveness in reducing COD and dye concentration emphasizes the potential of waste brick filters in wastewater treatment, though further optimization and regular maintenance are necessary for sustained performance.

4. Conclusion and Recommendations

The study demonstrates the potential of recycled waste bricks as an efficient and sustainable filtration medium for treating textile denim wastewater. The brick filtration system significantly reduced pollutants, particularly turbidity, chemical oxygen demand (COD), dye concentration, and total suspended solids (TSS) in the initial 4 days. The removal trend is observed to be continued and in two weeks, more than 95% of the major pollutants have been eliminated by the media. The porous nature of the bricks facilitated the adsorption and removal of suspended particles and dyes, while the physical structure helped with mechanical filtration. However, an increase in total dissolved solids (TDS) and electrical conductivity (EC) was noted, likely due to the leaching and desorption of minerals and ions from the bricks. These variations highlight the dynamic interaction between the wastewater and brick material, emphasizing the need for further studies to optimize the filtration process and minimize secondary contamination.

Overall, the results suggest that brick waste which is abundant in quantity and is a low-cost product, offers a promising green solution for cost-effective and environment-friendly textile wastewater management. This approach not only provides a sustainable wastewater treatment option but also contributes to resource conservation and the circular economy by turning construction waste into a valuable tool for water treatment.

In the future, this study may be expended for continuous mode and reusability studies may also be carried upon to further highlight the efficiency in multiple cycles in the batch mode.

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