Eco-Sustainable Use of Treated Textile Industry Effluent in Concrete Using Eichhornia Crassipes Ash as Bio-Adsorbent

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ABSTRACT

Discharge of industrial effluents in water bodies causes severe contamination in aquatic ecosystem. Eichhornia Crassipes, an economical and effective adsorbent has gained much interest in effluent treatment. This paper covers the details of Eichhornia Crassipes ash preparation, chemical properties and its adsorption mechanism on reducing the Total Dissolved Solids (TDS), chloride, sulphate content in the textile effluent. Eichhornia Crassipes ash was used in the dosages of 5 g/L, 10 g/L, 15 g/L, 20 g/L and 25 g/L to treat effluent, and the treated effluent has been used with potable water to produce concrete. Treated effluent was replaced with potable water in the proportions of 20%, 40%, 60%, 80% and 100%. The strength and durability properties of treated effluent incorporated concrete have been studied. The microstructure studies such as Scanning Electron Microscopy (SEM), X-ray Diffraction (XRD) and Fourier Transform Infrared Spectroscopy (FT-IR) have been carried out for the control and treated effluent added concrete. The TDS, chloride, sulphate content present in the textile effluent has been reduced up to 75% by the adsorption process. 40% of treated effluent can be replaced with potable water in the production of concrete with an increase in compressive strength by 2.43% and flexural strength by 4.83% without any reduction in quality of concrete.

Keywords: Textile effluent, Eichhornia Crassipes ash, adsorbent, treated effluent, concrete production

1. INTRODUCTION

In the present world, environmental pollution, particularly from industrial effluents, remains a critical global concern. Owing to speedy growth of numerous types of processing industries are instrumental in generating waste water effluents. Especially textile industries are one of the largest consumers of water, dyes and various processing chemicals that are used during various stages of textile processing [1-4]. Subsequently, substantial quantities of effluents are generated which are mostly left unutilized and not suitable for further usage. After production, effluents generated from various processes remain significant pollutants [5-7].

The textile effluent contains naphthol, sulphur, dyes, soaps, acetic acid, nitrates, chromium compounds and heavy metals like lead, nickel, cobalt, copper, arsenic, mercury and cadmium in tandem with formaldehyde based dyeing agents, hydro carbon softeners, auxiliary chemicals, stain removers, non-biodegradable dyeing chemicals [8-11]. Presence of such toxic chemical transforms the textile effluent in to a highly noxious and hazardous pollutant. These effluents are mostly not encompassed in the chemical-analytical control and monitoring sphere. Several treatment methods are available to treat the industrial effluents. Based on the nature of effluent, suitable treatment technique should be adopted [12-15].

Unscrupulous anthropogenic activity of disposing this hazardous effluent into water bodies particularly in rivers culminating in a colossal marine pollution and cause serious threats to marine ecosystem. Beside discharge of untreated effluents may increase the algal bloom in the stagnant waterbodies results in water depletion and contamination [16-20]. Conventional effluent treatment methods are not cost-effective, which prevents medium and small-scale industries from properly treating their effluents. Finding a suitable cost effective treatment method and viable alternative to reuse the textile effluent in safe and eco-friendly manner becomes order of the day to save marine environment [21-25].

Bio-coagulation is considered as one of the effective and economic treatment methods to treat textile effluent. Sayed et al. employed membrane technology to treat effluents from sewage treatment plants, palm oil mills, and hospitals. Overall, their study provided promising insights into the potential of bioremediation for diverse types of wastewaters. [44-48]. Eichhornia Crassipes ash ca used as a bio-coagulant in this study to treat textile effluent. Extensive presence of Eichhornia Crassipes in water bodies cause lot of troubles to the activities of aquatic livings and mankind [26-29].

Usage of Eichhornia Crassipes ash as a coagulant consists of several advantages, the focal advantages are eutrophication problem can be solved, the cost of coagulant in treatment process can be reduced and the time required for treatment also less if compared with other conventional treatment methods [30-32]. The ash can act as a natural pH buffer in effluent treatment, which is important for optimizing the conditions for the adsorption process. Many contaminants are more effectively removed at specific pH ranges, and using Eichhornia crassipes ash can help stabilize these conditions [58-61].

Instead of disposing the industrial wastewater into water bodies it can be treated and utilized as a useful ingredient in concrete blocks for construction. Researchers studied the feasibility of replacing potable water with treated effluent in concrete [39-43]. According to the researchers, around 450-480 L of water consumed for one-meter cube of concrete preparation. Construction sector is one of the largest consumers of water for several purposes [62-65]. Huge consumption of fresh water by the construction industry results in water scarcity. Utilization of treated effluent not only reduces pollution but also consumption of fresh water used for several purposes [49-52]. Hence an attempt has been made to replace potable water with treated effluent for production of concrete in construction. This study explores a dual-purpose solution by using Eichhornia Crassipes ash to treat textile effluent and reuse it as a mixing agent in concrete.

2. MATERIALS AND EXPERIMENTAL SET-UP

The techno-economic plausibility of treating textile effluent with Eichhornia Crassipes and reusing the treated effluent in concrete blocks based on experimental corroborations are furnished herewith. The procedural sequences concerned with the effluent treatment and reutilizing the treated effluent in the concrete matrix of the utility blocks with potable water are elaborated.

2.1 Eichhornia Crassipes and Textile effluent

The first step in the present investigation involves collection of textile effluent from textile industry in Tirupur, Tamilnadu, India. Eichhornia Crassipes was collected from nearby water bodies and sun-dried for 48 hours to remove the moisture present in it and using incineration process, the dried Eichhornia Crassipes was converted in to ash and sieved in 150 µm sieve. Thereafter sieved Eichhornia Crassipes ash in powdery form was used as an adsorbent in adsorption process of treating the textile effluents. The high surface area enhances its suitability as an adsorbent.

The primary functional groups present in Eichhornia Crassipes ash will act as adsorption sites when used as an adsorbent, amine (-NH_2) comprise carboxyl (-COOH), carbonyl (-C=O), and hydroxyl (-OH) groups; these oxygen-containing groups are primarily found within the cell wall components like cellulose, hemicellulose, and lignin, allowing the ash to bind to various pollutants through mechanisms like ion exchange, complexation, and chelation.

Eichhornia Crassipes contains following chemical elements Sodium, Aluminum, Oxygen, Carbon, Magnesium, Titanium, Zirconium, Potassium, Silicon. 1 Kg of dried water Eichhornia Crassipes was taken for incineration and 217 g of ash has been produced after incineration. Table.1 furnishes the chemical properties of Eichhornia Crassipes ash.

Table.1 Chemical properties of Eichhornia Crassipes ash

Parameters	Constituents (%)
CaO	17.1
SiO_2	23.6
Al_2O_3	3.93
Fe_2O_3	25.94
MgO	4.95
Na_2O	1.38
K_2O	1.54
SO_3	4.18
TiO_2	0.49
P_2O_5	4.79

The significant physio-chemical parameters of raw textile effluent were tested before coagulation process. Table.2 furnishes the physio-chemical parameters of raw effluent.

Table.2 Physio-chemical parameters of untreated effluent

Parameters	Values
Colour	Black
pH	5.6
TDS	9338 (mg/l)
Chlorides	1256 (mg/l)
Sulphates	691(mg/l)

2.3 Experimental set-up

The test set up for coagulation process is shown in figure.1. Eichhornia Crassipes ash in powdery form was sieved in 90μm sieve and added in different trial and error proportions to ascertain an optimal dosage of coagulant. Sedimentation aided with coagulation treatment was adopted to treat the raw effluent collected from the dyeing unit. A clari-flocculator was utilized in the process, with the experiment involving stepwise additions of Eichhornia crassipes ash as a coagulant at concentrations of 5 g/L, 10 g/L, 15 g/L, 20 g/L, and 25 g/L [26,27].

Fig.1 Coagulation process for treating textile effluent

Table 3 Effluent treatment details

Treatment ID	Description
UT	Untreated effluent
TC5	Effluent treated with coagulant at concentrations of 5 g/L
TC10	Effluent treated with coagulant at concentrations of 10 g/L
TC15	Effluent treated with coagulant at concentrations of 15 g/L
TC20	Effluent treated with coagulant at concentrations of 20 g/L
TC25	Effluent treated with coagulant at concentrations of 25 g/L

The treatment details are shown in table 3. The contact time for coagulation was taken as 30 minutes for coagulation. The prominent influencing parameter viz, Total Dissolve Solids (TDS), pH, Sulphate and Chloride of raw and treated textile effluent were tested and compared with prescribed limits specified in IS 456 (2000). After coagulation the supernatant treated effluent solution is separated and blended with potable water in different ratios to reuse as mixing water in concrete blocks.

The treated textile effluent was blended with potable water in the ratios 20:80, 40:60, 60:40 and 80:20. The mixes were denoted as TE20, TE40, TE60 and TE80 respectively. Mould cast samples of size 100x100x100 mm were cast using treated effluent and potable water. Samples were tested against compressive strength after 7 and 28 days of curing. Similarly, prisms of size 100x100x500 mm were cast tested against flexural strength. Both compressive and flexural strength of treated effluent imbibed concrete samples were compared with conventional concrete.

In order to ascertain the probability of corrosion, Half-cell potential test was performed for both conventional and treated effluent added concrete samples as per ASTM C876-15. Study has been conducted for the duration of 56 days at an interval of 7 days and the concrete samples were investigated to assess the probability of corrosion. Based on the test results, the durability of the treated effluent imbibed and conventional concrete samples has been analysed.

3. Results and Discussions

3.1 Efficiency of adsorbent in effluent treatment process

Eichhornia Crassipes ash has been added in different dosages and the efficiency of the adsorbent has been evaluated. Influence of adsorbent on reduction of TDS, chloride and sulphate has been assessed. The variations in alkalinity of the treated effluent for different dosages of adsorbent also studied.

3.1.1 Influence of Eichhornia Crassipes ash on Alkalinity of Effluent

Ash of dried bio materials attained from Eichhornia Crassipes aids in the biosorption (biological adsorption) of the venomous components of effluent. The pH value of treated effluent and untreated effluent were calculated and the influence of adsorbent dosage has been assessed. The untreated effluent obtained from the industry was slightly acidic in nature and the pH value found to be 5.6. The pH value of treated effluent is higher than that of untreated effluent for all the treatments. The main reason for increase in alkalinity is due to the presence calcium oxide in ash [33,34].

Calcium oxide reacts with hydrogen ions present in water and forms calcium hydroxide. This chemical reaction increases the pH value of the effluent. The pH value of treated textile effluent with different dosage of adsorbent at desired dilution levels is shown in fig.3. From the experimental result it was observed that up to treatment TC20, the pH value has been considerably increased. It has gained pH value of more than 9. Later a slight variation was observed. pH value of water more than 6 is ideal for hydration of cement particles. The cement itself is alkaline, and mixing with slightly higher alkaline water ensures that the chemical reactions involved in cement hydration proceed properly. The pH value of potable water found to be 7.72. Fig.2 shows the pH variations of effluent with respect to dosage of adsorbent.

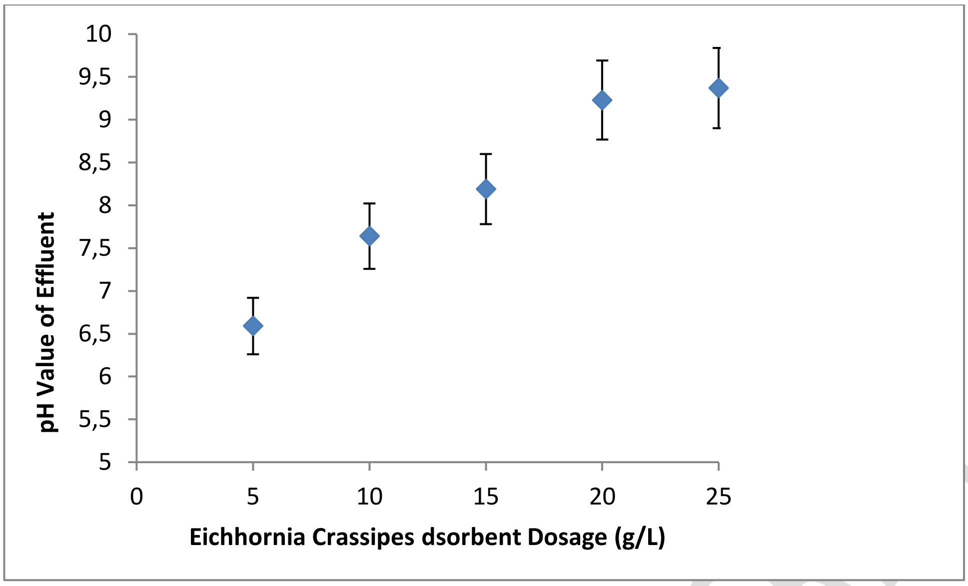


Fig.2 pH value of treated effluent with different dosage of adsorbent

3.1.2 Influence of Eichhornia Crassipes ash on TDS reduction of Effluent

TDS is one the key parameter considered in assessing the quality of the treated effluent to confirm its suitability to reuse it. The untreated effluent has the Total Dissolved Solids value of 9338 ppm. The higher TDS content of the effluent may be the presence of various salts in the effluent. The TDS content has been considerably reduced after effluents were subjected adsorption process. The rate of adsorption increases with respect adsorbent dosage that tends to reduce the TDS of the effluent. It was noted that the percentage of adsorption found to be very minimal between treatments TC20 and TC25.

Compared with the untreated effluent, from the experimentation the removal percentage of TDS in the treated effluent found to be 10.52%, 26.83%, 41.2%, 75.84% and 76.02% for the treatments TC5, TC10, TC15, TC20, and TC25 respectively. The reduction in TDS content may be due to the attraction of solute molecules with the surface of the adsorbent through functional groups over the surface [35,36]. During adsorption process, solute molecules accumulated in the adsorbent. If negative charge is found, the ions are transferred and stored in the adsorbent. Fig.3 illustrates the TDS values of treated textile effluent with different dosage of adsorbent.

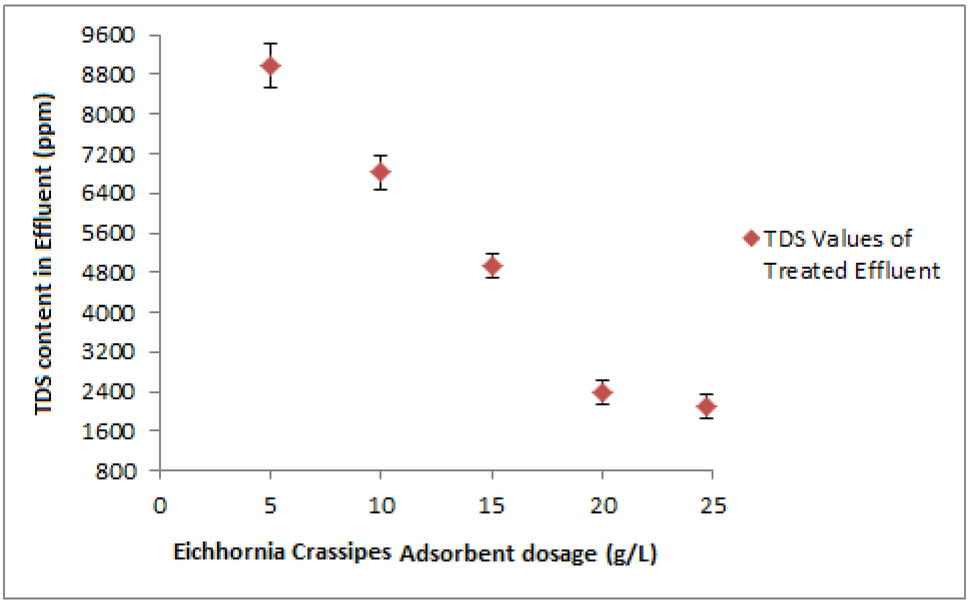


Fig.3 TDS variations of treated effluent with different dosage of adsorbent

3.1.3 Influence of Eichhornia Crassipes ash on reduction of chloride in effluent

Chloride is the most common salt present in effluents obtained from industries. Most of the industries using acids like HCI and H_2SO_4 in their processing units. In order to neutralize the acidic nature of the solution, NaOH or $Ca(OH)_2$ is largely used. Obviously, usage of NaOH or $Ca(OH)_2$ increase the chloride content in the wastewater and make it unsuitable for reutilization. Bio-adsorption process considerably reduces the chloride content present in the effluent. The chloride content of untreated effluent collected from the industry found to be 1256 mg/L.

Based on the experimental results, the percentage removal of chloride in the treated effluent found to be 16.7%, 27.3%, 42.14%, 54.7% and 55.8%for the treatments TC5, TC10, TC15, TC20, and TC25 respectively. The reduction in chloride content may be due to the attraction of solute molecules with the surface of the adsorbent through functional groups over the surface [37]. Silica is a major component that can enhance adsorption by providing a porous structure. Calcium and magnesium have the ability to neutralize acidic components in the effluent and assist in ion exchange processes. Similarly, Potassium and Sodium plays a vital role in ion exchange and increase the adsorptive capacity for specific pollutants. Besides, Phosphorus and Iron can react with heavy metals and other pollutants, potentially precipitating them out of the solution. Fig.4 illustrates the chloride values of treated textile effluent with different dosage of adsorbent.

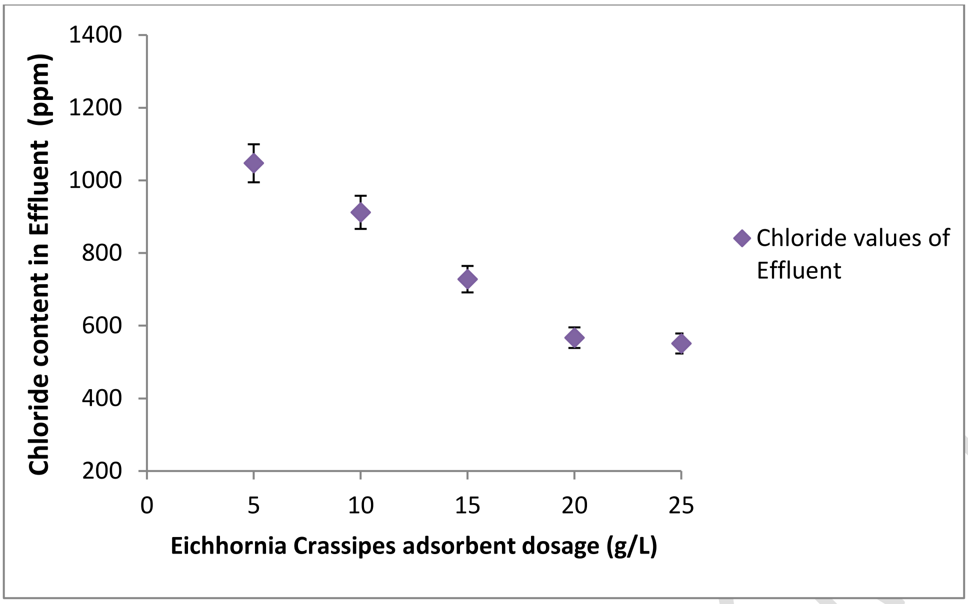


Fig.4 Chloride values of treated textile effluent with different dosage of adsorbent

3.1.4 Influence of Eichhornia Crassipes ash on reduction of sulphate in effluent

Removing sulphate ions in effluent is a critical process because of its higher solubility and stability. Most of the industrial effluents consist of higher level of sulphates. If the sulphate level is greater than 250 mg/L then the effluent become more corrosive in nature and that may corrode the discharge pipes. The sulphate content of untreated effluent collected from the industry found to be 691 mg/L. Usage of bio-sorbent reduces the sulphate content in the effluent. Since the removal of sulphate ions in effluent is a tedious process, bio-sorption is the ideal method for treatment [Abdelfattah et.al. (2023), Mohammed Benjelloun et.al, (2021), Yadav et.al, (2019)]

The increase in adsorbent dosage tends to increase the removal efficiency of sulphate ions. This may be due to the higher surface area and pore volume of the adsorbent results in more functional groups for adsorption [38]. A small dip in removal efficiency was observed for the adsorbent dosage 25g/L. This reduction may be due to the partial blockage of the adsorbent's pore structure by fine particles of coagulant. The percentage removal of sulphate in the treated effluent found to be 10.9 %, 18.38 %, 29.53 %, 42.84 % and 43.2 % for the treatments TC5, TC10, TC15, TC20, and TC25 respectively. Fig.5 illustrates the sulphate values of treated textile effluent with different dosage of adsorbent.

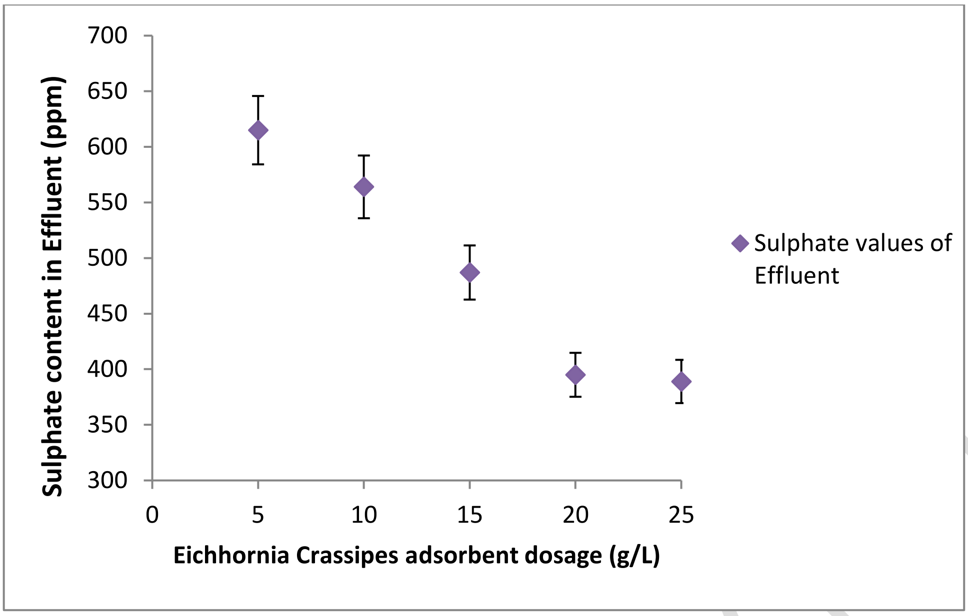


Fig.5 Sulphate values of treated textile effluent with different dosage of adsorbent

3.2 Influence of treated effluent with potable water on strength properties of concrete

For varying percentage proportions of treated effluent with potable, concrete samples have been produced and tested for its strength and durability to assess the influence of effluent. Samples were prepared for the mixes TE20, TE40, TE60 and TE80.

3.2.1 Influence of treated effluent on 7 days compressive strength of concrete

The 7 days compressive strength variations observed from experimentation with respect to the incremental changes in the percentage additions of treated effluent with potable water were plotted as a scatter diagram as shown in Fig.6. The percentage increase in compressive strength found to be 6.8%, and 3.3% for the mixes TE20, and TE40 respectively. Reduction in compressive strength for observed for the mixes TE60 and TE80.

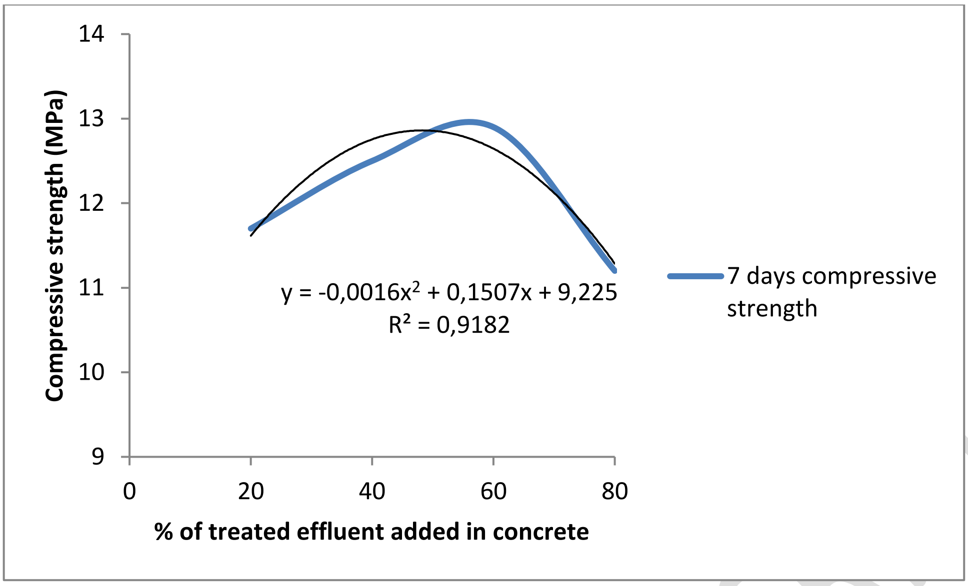


Fig.6 Compressive strength variations of treated effluent concrete at 7 days

The best fitting non-linear curve corresponding to a quadratic equation of the form $y = ax^2 + bx + c$ was fitted with a dependable correlation level of 91.8 %, the prediction obtained was $y = -0.0016x^2 + 0.1507x + 9.225$ MPa. Where y is the compressive strength of MPa and x is the percentage proportioning of added treated effluent in concrete. It was noted from the prediction curve that the compressive strength has been at increasing rate with increasing percentage additions of treated effluent up to 40%.

3.2.2 Influence of treated effluent on 28 days compressive strength of concrete

The 28 days compressive strength of treated effluent incorporated concrete for different percentage additions of treated effluent with potable water were plotted and shown in Fig.7. The percentage increase in 28 days compressive strength found to be 5.57%, and 2.43% for the mixes TE20, and TE40 respectively. It was observed that the compressive strength of mixes TE60 and TE80 found to be less than that of control concrete.

In the sequence of complementary strength analysis, the prediction $y = -0.0022x^2 + 0.2172x + 19.725$ MPa with a dependable correlation level of 93.29 % has been used to predict the 28 days compressive strength, where y is the 28 days compressive strength of MPa and x is the percentage proportioning of added treated effluent in concrete. Test results revealed that the compressive strength has been increased up to 40% additions of treated effluent with potable water.

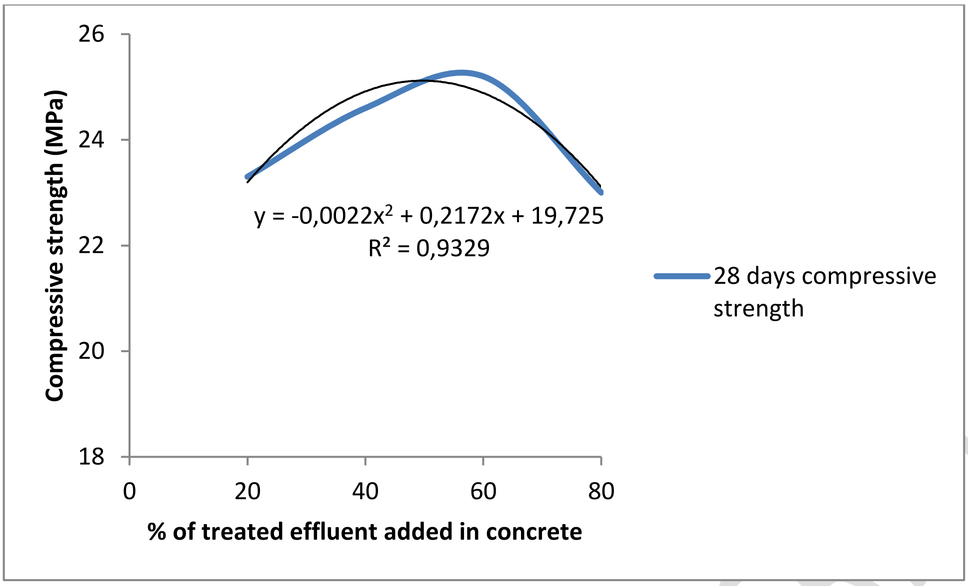


Fig.7 Compressive strength variations of treated effluent concrete at 28 days

3.2.3 Influence **of treated effluent on 7 days flexural strength of concrete**

Treated effluent imbibed concrete prisms were subjected to flexural strength test and it was observed that mixes TE20 and TE40 obtained higher flexural strength than the control mix at 7 days of curing. This may be due to the micro pore filling effect of the minute particle present in treated effluent which increases the density of the cement matrix [53,54]. The 7 days flexural strength variations of treated effluent incorporated concrete for different mixes were plotted and shown in Fig.8.

The 7 days flexural strength has been predicted using the equation y = -0.0005x2 + 0.033x + 4.2 MPa with a dependable correlation level of 91.11 %, Where y is the 7 days flexural strength of MPa and x is the percentage proportioning of added treated effluent in concrete. Test results indicated that the mixes TE20 and TE40 obtained 6.97% and 6.52% higher flexural strength than the control mix. Beyond 40% addition of treated effluent with potable water reduced the flexural strength of concrete.

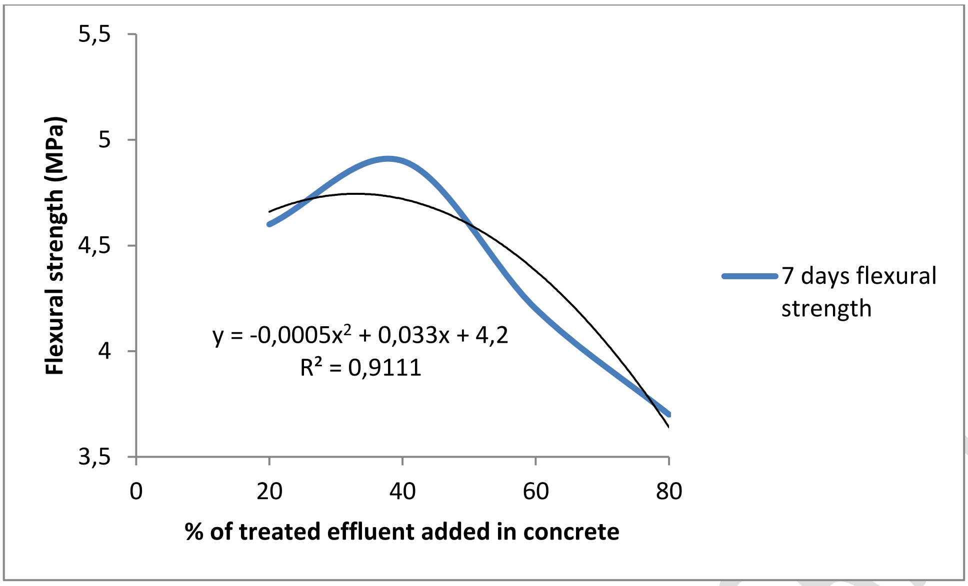


Fig.8 Flexural strength variations of treated effluent incorporated concrete at 7 days

3.2.3 Influence of treated effluent on 28 days flexural strength of concrete

In line with the 7 days flexural strength, the same escalating trend was observed in the 28 days flexural strength of treated effluent imbibed concrete for the mixes TE20 and TE40. In case of mixes TE60 and TE80, a declining trend in flexural strength was observed due to the minute dissolve particles present in the treated effluent which may affect the hydration process of in the cement mantle [55,56]. The 28 days flexural strength of treated effluent incorporated concrete for different mixes are shown in Fig.9.

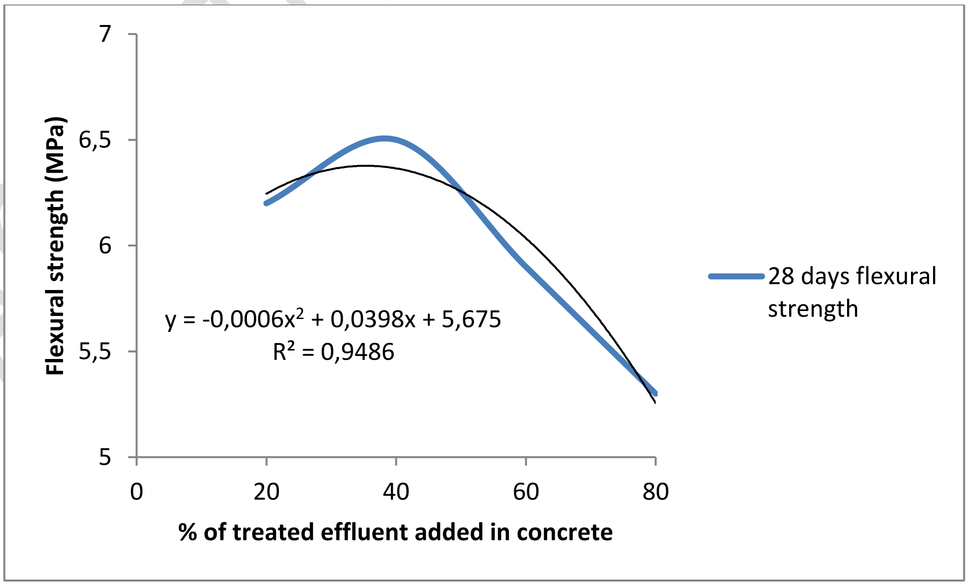


Fig.9 Flexural strength variations of treated effluent incorporated concrete at 28 days

The curve fitting equation $y = -0.0006x^2 + 0.0398x + 5.675$ MPa at a dependable correlation of 94.86 % of the data has been used to predict the 28 days flexural strength of treated effluent incorporated concrete. Where y is the 28 days flexural strength of MPa and x is the percentage proportioning of added treated effluent in concrete. Compared with control concrete, the percentage increase in flexural strength for the mixes TE20 and TE40 found to be 6.89% and 4.83% respectively. Reduction in flexural strength was observed for the mixes TE60 and TE80. Based on the experimental results, it was test verified that up to 40% of potable water can be replaced with treated effluent in concrete. The experimental results showed good agreement with the predicted values, indicating that the experimental outcomes closely matched the validation results [65, 66].

3.2.4 Empirical relationship between compressive and flexural strength

Quality of concrete primarily assessed based on its strength. In this study, based on experimentally obtained data, an empirical correlation equation has been developed to assess the flexural strength of treated effluent imbibed concrete from its compressive strength. The compressive and flexural strength of TE20, TE40, TE60 and TE80 mixes were analysed and the following relationship has been developed between the 28 days compressive and flexural strength of treated effluent imbibed concrete [24-27], as expressed in Eq. (1):

$$f_f = 0.0118.(f_c)^{1.4936} \text{ MPa} \quad (1)$$

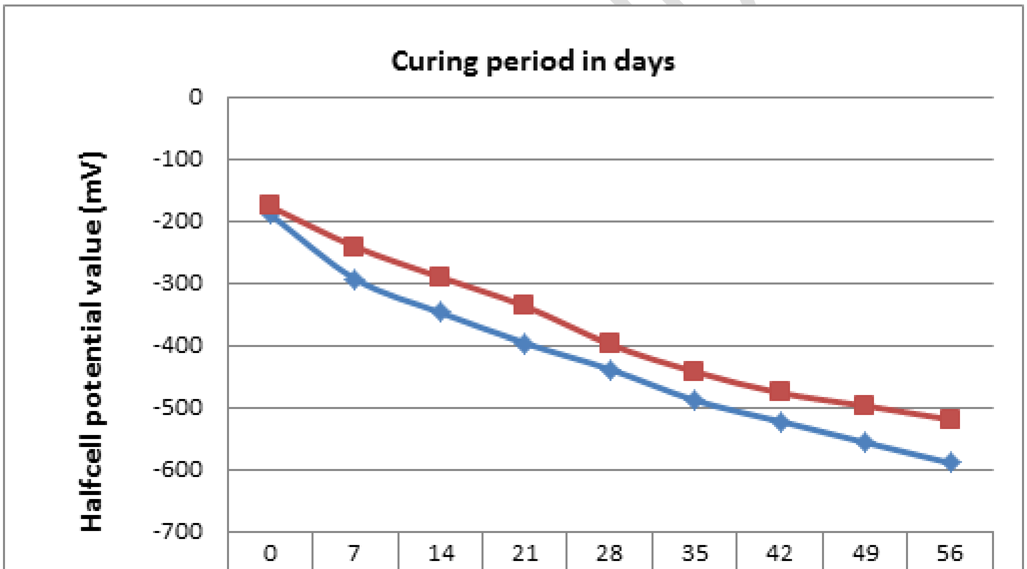
Where, f_f and f_c denote the 28-day flexural and compressive strengths of treated effluent imbibed concrete, expressed in MPa, respectively. The co-efficient of determination obtained from the regression equation shows 94.2% confidence. The percentage error was only 5.8 % which clearly indicated the reliability of the developed empirical equation in assessing the strength variations.

3.3 Probability of corrosion in treated effluent imbibed concrete

The corrosion activity of rebar in concrete is a critical factor for the durability and longevity of reinforced concrete structures. Half-Cell Potential test is one of the common non-destructive methods used to assess the corrosion activity of the embedded reinforcement (rebar) without removing or damaging the concrete. The corrosion behaviour of rebar embedded in the mix TE40 has been evaluated using the Half-Cell Potential method and compared with control mix.

The test involves measuring the electrical potential difference between a reference electrode (typically a copper-copper sulfate electrode) placed on the concrete surface and the rebar inside the concrete. The potential difference indicates the electrochemical activity of the rebar, which correlates with the probability of corrosion. TE40 mix was assessed by monitoring the potential variations in the rebar over time. Concrete samples were immersed in 3.5 % NaCl solution.

Measurements were taken on a weekly basis to assess the rate of corrosion in rebar and the tests were performed until the concrete began to separate from the reinforcing bar (which indicates significant corrosion-induced damage). The probability of corrosion found to be 17.75%, 16.43%, 14.9%, 9.13%, 9.43%, 8.81%, 10.61%, 12.39% less at 7, 14, 21, 28, 35, 42, 49 and 56 days of curing for the mix TE40 than the control mix respectively. The main reason for less probability of corrosion is clogging of micro pores of concrete by dissolved particles present in treated effluent [57]. Half-cell potential values are shown in Fig.10.



	0	7	14	21	28	35	42	49	56
CC	-189	-293	-347	-396	-438	-488	-522	-556	-589
TE40	-176	-241	-290	-337	-398	-442	-476	-497	-519

Fig.10 Half-cell potential values of control mix and TE40 mix

3.4 Scanning Electron Microscopy Analysis

Scanning Electron Microscopy (SEM) analysis of treated effluent-added concrete helps to study the microstructural characteristics of concrete when treated wastewater (effluent) is used in the mix. The surface morphology and microstructure of the conventional and effluent added concrete (Mic TE40) has been studied to understand how the incorporation of treated effluent impacts its properties at the microscopic level. The presence of organic or inorganic compounds may alter the pore size distribution of the cement matrix

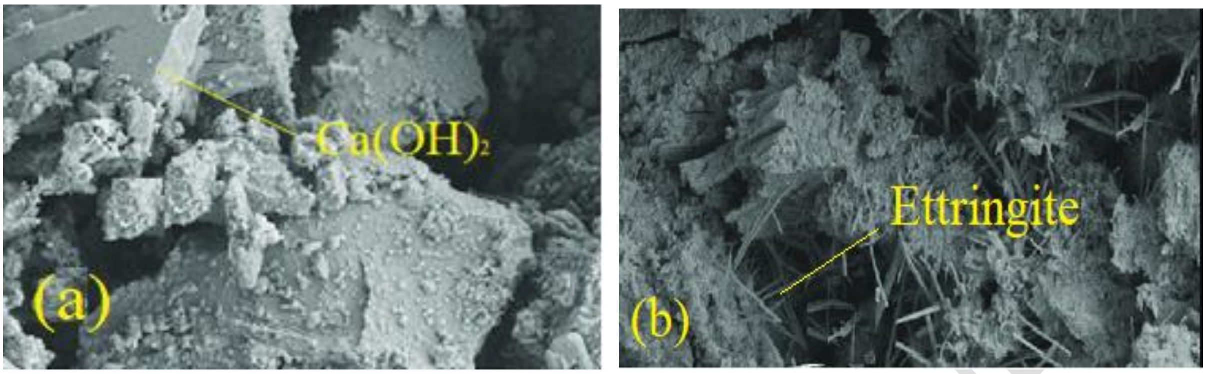


Fig.11 SEM image of (a) Control concrete (b) Effluent added concrete

Fig.11 shows the SEM image of control concrete and effluent added concrete. The existence of organic matter or high amounts of dissolved salts from the effluent can potentially clog or block the pores and reduced the porosity of the concrete. SEM images clearly indicated the formation of calcium hydroxide (CH) and ettringite in the concrete. Treated effluent containing sulphates or chlorides that may promote the formation of ettringite in the cement mantle, which could indicate the reaction of these materials with hydrated products.

3.5 FT-IR Analysis

FT-IR spectroscopy is a powerful technique used to identify and quantify the chemical bonds and functional groups in a sample, based on the absorption of infrared light at specific wavelengths. Figure 6 presents the FT-IR spectra for both the control mix and TE40 sample after a curing period of 28 days. In the FT-IR spectra of both the control and TE40 samples, two prominent bands appear at 3496 cm−1 and 1040 cm−1. These bands are associated with the bending vibrations of the -OH (hydroxyl) groups present in water molecules. The band at 3496 cm−1 specifically corresponds to the O-H stretching vibration, which is characteristic of water. The band at 1040 cm−1 is typically assigned to the bending vibration of the O-H bond in water molecules, which also confirms the presence of water in the sample. This observation aligns with findings in previous studies [14, 27, 28].

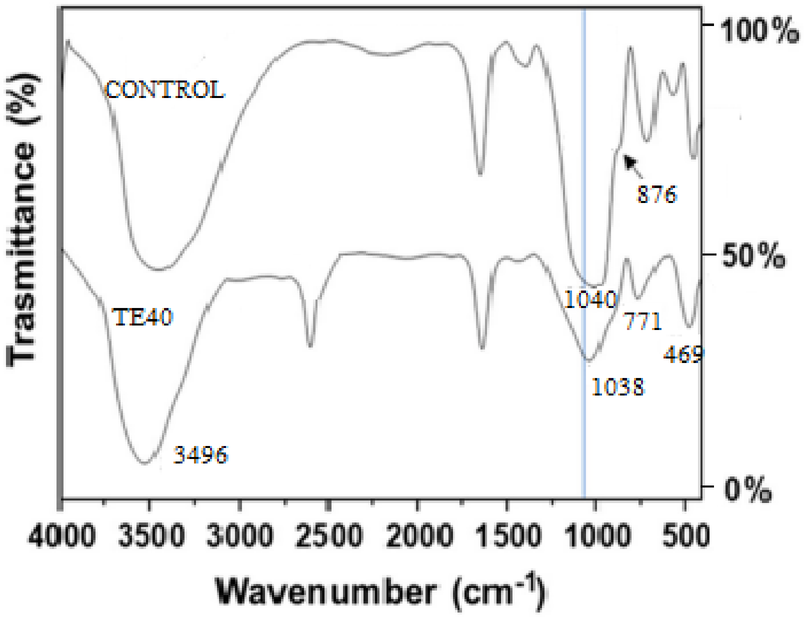


Fig. 12 FT-IR spectra of control mix and mix TE40

Furthermore, two additional peaks observed at 876 cm−1 and 771 cm−1 in both the control and TE40 spectra are indicative of the Si-O stretching vibrations. These peaks suggest the presence of ettringite, a common hydration product in cementitious materials. Ettringite is formed as a result of the reaction between calcium hydroxide (produced during cement hydration) and aluminum compounds. The presence of these bands at 876 cm−1 and 771 cm−1 strongly supports the idea that ettringite is present in the cured mixes, confirming the formation of this hydration product. This process is particularly important in systems where treated wastewater is used as a blending material in concrete.

3.6 XRD Analysis

The composition of treated effluent generally varies depending on its source, but it usually contains dissolved organic and inorganic substances, including salts, heavy metals, sulfates, and chlorides. These constituents might react with the ingredients in the concrete, affecting the hydration process and altering the mineral phases in the resulting concrete matrix.

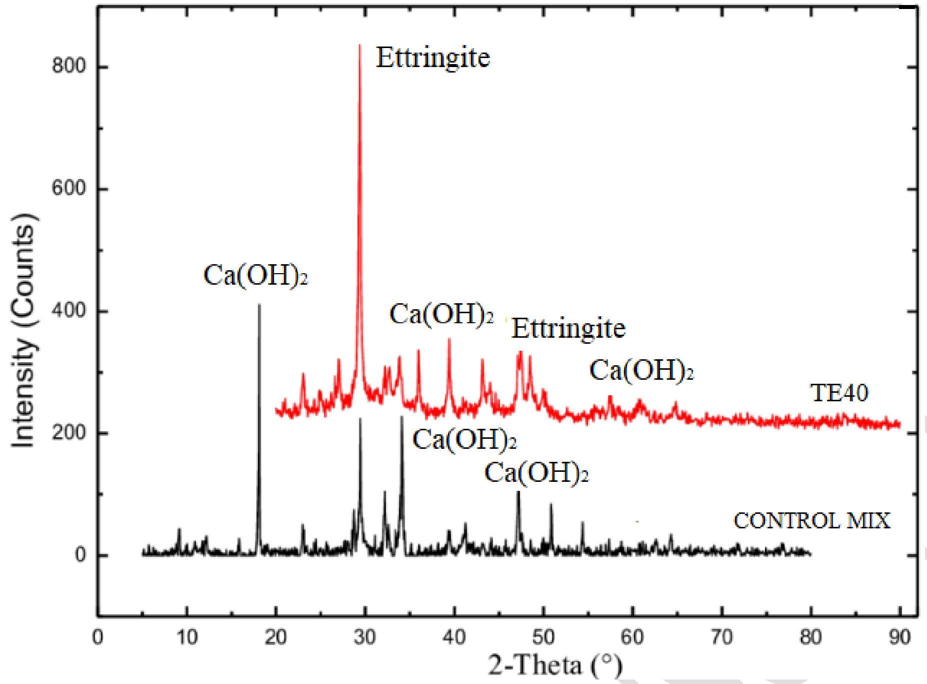


Fig.13 XRD Pattern of control mix and TE40

Treated effluent may influence the hydration of cement by introducing additional chemical ions, which can either accelerate or retard the hydration reactions. The presence of ettringite was identified through XRD analysis in the wastewater incorporated concrete. This is due to availability of excess of sulfate minerals which may lead to a greater formation of ettringite. Calcium hydroxide formation could occur due to an imbalance in the chemical reactions when treated wastewater contains high levels of calcium ions.

3.7 Limitations and Economical feasibility for Implementation

Eichhornia crassipes ash is an eco-friendly bio-adsorbent for wastewater treatment but there is several limitations related to its adsorption capacity, surface properties, and regeneration potential. Addressing these challenges through research on surface modifications, adsorption mechanisms, and large-scale applications will be essential for making this material a viable alternative to synthetic adsorbents. In future research by exploring surface modification techniques (e.g., activation, functionalization, or impregnation with other materials) the surface area can be increased to enhance the adsorption properties of the ash. This could increase its efficiency of the Eichhornia Crassipes ash than other bio-adsorbents. Coagulation is the main process involved in this type of treatment hence this method economically feasible and scalable for real-world application.

4 Conclusion

The experimental investigation revealed the potential use of Eichhornia Crassipes ash as an adsorbent in effluent treatment. The following conclusions have been drawn from the experimentation.

- The pH value of effluent subjected to treatment TC20 found to be 9.23 which is alkaline in nature and suitable for reuse.
- The Total Dissolved Solids (TDS) content in the effluent treated with TC20 was reduced by 75.84% compared to the untreated effluent, bringing the TDS levels within the permissible limits for reuse.
- The chloride concentration in the treated effluent under TC20 treatment showed a 54.7% reduction relative to the untreated sample.
- Similarly, the sulphate content in the TC20-treated effluent was 42.8% lower than that in the untreated effluent.
- With respect to the use of treated effluent in concrete production, the mix designated as TE40 was identified as the optimal composition, demonstrating no adverse effects on strength and durability.
- TE40 exhibited a 3.3% and 2.43% increase in compressive strength over the control mix at 7 and 28 days of curing, respectively.
- In terms of flexural strength, TE40 achieved improvements of 6.52% and 4.83% at 7 and 28 days of curing when compared to the control mix.
- Corrosion potential in reinforcing bars embedded in TE40 concrete samples was found to be lower than that in the control mix, indicating enhanced durability performance.
- Based on the experimental findings, it can be concluded that up to 40% of treated effluent can effectively replace potable water in concrete production without compromising the material's strength or durability.

5 References

[1] Rabiranjan Murmu, Santhi M. George, Yuvarani P, Priyanka Bhatnagar, Amudha K and Karuna M. S, (2024). Sustainable Solutions for Heavy Metal Contamination: Characterization and Regeneration of Eichhornia Crassipes Biosorbent in Wastewater Treatment" Global NEST Journal, 26,1-8.

[2] M.H Ullah, M.J Rahman, (2024) Adsorptive removal of toxic heavy metals from wastewater using Eichhornia Crassipes and its biochar: A review, Heliyon, 10, 1-20.

[3] B. Pratap et al., (2023). Wastewater generation and treatment by various eco-friendly technologies: possible health hazards and further reuse for environmental safety. Chemosphere, 313- 137547.

[4] A. Abdelfattah, et.al., (2023). Microalgae-based wastewater treatment: mechanisms, challenges, recent advances, and future prospects. Environmental Science and Ecotechnology 13, 1-18.

[5] H. Elbasiouny. et. al. (2021). Ecofriendly remediation technologies for wastewater contaminated with heavy metals with special focus on using Eichhornia Crassipes and black tea wastes: a review. Environmental Monitoring and Assessment. 193, 1–19.

[6] C. Liu, J. et. al. (2020). Removal of Cadmium (II) using Eichhornia Crassipes (Eichhornia crassipes) biochar alginate beads in aqueous solutions. Environment Pollution. 264, 1-7.

[7] J.A. Siddique. (2023). Nanofiltration membrane use for separation of heavy metals from wastewater. Emerging Techniques for Treatment of Toxic Metals from Wastewater. 523–549.

[8] D. Hemalatha, R. Narayanan, S. Sanchitha. (2021). Removal of Zinc and Chromium from industrial wastewater using Eichhornia Crassipes (E. crassipes) petiole, leaves and root powder: equilibrium study, Materials Today Proceedings.43.1834–1838.

[9] M. Yadav, R. Gupta, R.K. Sharma. (2019). Green and sustainable pathways for wastewater purification. Advances in Water Purification Techniques. 355–383.

[10] J. Fito, T.T. Nkambule. (2023) Synthesis of biochar-$CoFe_2O_4$ nanocomposite for adsorption of methylparaben from wastewater under full factorial experimental design, Environmental Monitoring and Assessment. 195.

[11] Xutong Ma, et.al (2022). A novel natural lignocellulosic biosorbent of sunflower stem-pith for textile cationic dyes adsorption, Journal of Cleaner Production, 331- 129878.

[12] Tabrez Alam Khan, et.al (2022). Adsorptive scavenging of cationic dyes from aquatic phase by H_3PO_4 activated Indian jujube (Ziziphus mauritiana) seeds based activated carbon: Isotherm, kinetics, and thermodynamic study, Journal of Saudi Chemical Society, 26. 1-16.

[13] Sanmuga Priya, E., Senthamil Selvan, P. (2014). Eichhornia Crassipes (Eichhornia crassipes) – An efficient and economic adsorbent for textile effluent treatment – A review. Arabian Journal of Chemistry. 10. S3548-S3558.

[14] Grag, V.K., Raksh Kumar and Renuka Gupta. (2004). Removal of malachite green dye from aqueous solution by adsorption using agro industries waste: A case study of Phosopis ceneraria. Dyes & Pigments. 62. 1-10.

[15] Gercel, O., Gercel, H. F., Koparal, A. S. and U.B.O gutveren (2008) Removal of disperse dye from aqueous solution by novel adsorbent prepared from biomass plant material. Journal of Hazardous Materials. 160. 668-674.

[16] Robinson, T G. McMullan, Marchant, R. Nigam P. (2001). Remediation of dyes in textile effluent: a critical review on current treatment technologies with a proposed alternative. Bioresource Technology. 77. 247–255.

[17] Jamaluddin, A. M. and Nizamuddin, M. (2012). Physicochemical Assessment of Textile Effluents in Chittagong Region of Bangladesh and Their Possible Effects on Environment. International Journal of Research in Chemistry and Environment. 2. 220-230.

[18] Mohammed Benjelloun, et.al. (2021). Recent Advances in Adsorption Kinetic Models: Their Application to Dye Types. Arabian Journal of Chemistry, 14. 1-24.

[19] M.K. Abd Elnabi. et al. (2023). Toxicity of heavy metals and recent advances in their removal: a review. Toxics. 11- 580.

[20] M.O. Idris, et.al. (2023). Introduction of adsorption techniques for heavy metals remediation. Emerging Techniques for Treatment of Toxic Metals from Wastewater. pp. 1–18.

[21] H. Pezeshki, M. Hashemi, S. Rajabi. (2023). Removal of arsenic as a potentially toxic element from drinking water by filtration: a mini review of nano filtration and reverse osmosis techniques, Heliyon. 9.1-10.

[22] N. Abdullah, N. Yusof, W. Lau, J. Jaafar, A. Ismail. (2019). Recent trends of heavy metal removal from water/wastewater by membrane technologies, Journal of Industrial and Engineering Chemistry. 76. 17–38.

[23] S. Ramos-Vargas, R. Huirache-Acuna, J. Guadalupe Rutiaga-Quinones (2020). Effective lead removal from aqueous solutions using cellulose nanofibers obtained from Eichhornia crassipes, Water Supply. 20. 2715–2736.

[24] P. Kumar, M. Chauhan. (2019). Adsorption of chromium (VI) from the synthetic aqueous solution using chemically modified dried Eichhornia Crassipes roots, Journal of Environmental Chemical Engineering. 7- 103218.

[25] M. Zubir, et.al. (2020). The mixture of Eichhornia Crassipes plant and Chitosan-Bentonite as a modified absorbent for PB (II) removal in liquid waste, Pollut. Res. 39 (2020) 298–

[26] P. Grenni, et al. (2019). Effectiveness of a new green technology for metal removal from contaminated water. Microchemical Journal. 147. 1010–1020.

[27] P. Singh, S. Sharma, M. Dhanorkar. (2023). Aquatic plant biomass-derived porous carbon: biomaterials for sustainable waste management and climate change mitigation, International Journal Environmental Science and Technology. 20 .12955–12970.

[28] Q. Huang, S. Song, Z. Chen, B. Hu, J. Chen, X. Wang. (2019). Biochar-based materials and their applications in removal of organic contaminants from wastewater: state-of-the-art review. Biochar.1.45–73.

[29] Y. Zhou, L. Zhang, Z. Cheng (2015). Removal of organic pollutants from aqueous solution using agricultural wastes: a review, Journal of Molecular Liquids 212. 739–762.

[30] M. Carvalho Dos Santos, E. Lenzi. (2000). The use of aquatic macrophytes (Eichhornia crassipes) as a biological filter in the treatment of lead contaminated effluents, Environmental Technology. 21. 615–622.

[31] X. Lu, M. Kruatrachue, P. Pokethitiyook, K. Homyok (2004). Removal of cadmium and zinc by Eichhornia crassipes, Eichhornia crassipes, Science Asia. 30. 93- 103.

[32] J.-C. Zheng, et. al. (2016). Competitive sorption of heavy metals by Eichhornia Crassipes roots. Environmental Pollution.219. 837–845.

[33] H.S. Ibrahim, N.S. Ammar, M. Soylak, M. Ibrahim. (2012). Removal of Cd (II) and Pb (II) from aqueous solution using dried Eichhornia Crassipes as a biosorbent, Spectrochimica Acta PartA Molecular and Biomolecular Spectroscopy. 96. 413–420.

[34] S.H. Hasan, M. Talat, S. Rai (2007). Sorption of cadmium and zinc from aqueous solutions by Eichhornia Crassipes (Eichchornia crassipes). Bioresource Technology. 98.918–928.

[35] G.K.Arunvivek, G.Maheswaran, S.Senthilkumar. (2015). Experimental study on Influence of Recycled Fresh Concrete Waste Coarse Aggregate on properties of Concrete. International Journal of Applied Engineering Research. 10. 2809-2815.

[36] Asadollahfardi, G.; Mahdavi, A.R. (2019). The feasibility of using treated industrial wastewater to produce concrete. Struct. Concrete. 20. 123–132.

[37] Agwe, T.M et.al. (2022). Concrete Production and Curing with Recycled Wastewater: A Review on the Current State of Knowledge and Practice. Advances in Civil Engineering. 1-10.

[38] Zeyad, A.M. (2023). Sustainable concrete Production: Incorporating recycled wastewater as a green building material. Construction and Building Materials. 407- 133522.

[39] Soltanianfard, M.A et.al. (2023). Sustainable concrete made with wastewater from different stages of filtration. Construction and Building Materials. 409- 133894.

[40] G.K.Arunvivek, et.al. (2020). Feasibility study on utilization of sisal fiber and crushed tile in concrete utility block, International Journal of innovations in Scientific and Engineering Research.7. 189-195.

[41] Ghrair, A.M. et.al. (2018). Influence of grey water on physical and mechanical properties of mortar and concrete mixes. Ain Shams Engineering Journal. 9.1519–1525.

[42] Zarimah Mohd Hanafiah, et.al. (2024). Removal of pharmaceutical compounds from sewage effluent by the nanofiltration membrane, Journal of Water Process Engineering, 68-106320.

[43] Sayed, K., et.al (2022). Optimization of palm oil mill effluent final discharge as biostimulant for biodegradation of tapis light crude petroleum oil in seawater. Journal of Sea Research. 188 -102268.

[44] Khalid Sayed, et.al. (2024). Simultaneous enhanced removal of pharmaceuticals and hormone from wastewaters using series combinations of ultra-violet irradiation, bioremediation, and adsorption technologies, Journal of Water Process Engineering, 57-104589.

[45] Khalid Sayed et.al. (2021). Potential biodegradation of Tapis Light Crude Petroleum Oil, using palm oil mill effluent final discharge as biostimulant for isolated halotolerant Bacillus strains. Marine Pollution Bulletin.172 -112863.

[46] Zarimah Mohd. Hanafiah, et.al. (2024). Removal Of Pharmaceuticals from Municipal Wastewater Using Malaysian Ganoderma Lucidum Fungal Strain. Chemosphere. 358-142209.

[47] Miller, S.A et.al. (2018). Impacts of booming concrete production on water resources worldwide. Nature Sustainability.1. 69–76.

[48] Ahmed, S et.al. (2021). Effect of recycled aggregates and treated wastewater on concrete subjected to different exposure conditions. Construction and Building Materials. 266- 120930.

[49] G. K Arunvivek, D. Rameshkumar. (2022). Experimental Investigation on Feasibility of utilizing Phosphogypsum in E-Glass Fiber-incorporated Non-fired Ceramic Wall Tile. Journal of the Institution of Engineers (INDIA): Series A. 103. 445–451.

[50] Deldar, O et.al. (2024). Assessing the Impacts of Treated Wastewater on Concrete's Mechanical Properties and Corrosion Resistance. Iranian Journal of Science and Technology, Transactions of Civil Engineering. 4093-4112.

[51] Peighambarzadeh, F.S et.al. (2020). The effects of using treated wastewater on the fracture toughness of the concrete. Australian Journal of Civil Engineering. 18. 56–64.

[52] Raza, A et.al. (2020). Performance evaluation of concrete developed using various types of wastewater: A step towards sustainability. Construction and Building Materials.262-120608.

[53] G.K.Arunvivek, et.al. (2015). Eco-friendly Solution to Mitigate the Toxic Effects of Hazardous construction Industry waste by Reusing in concrete for Pollution Control. Nature Environment and Pollution Technology.14. 963-966.

[54] Varshney, H et.al. (2021). Sustainable use of different wastewater in concrete construction: A review. Journal of Building Engineering. 41- 102411.

[55] Meena, K.; Luhar, S. (2019). Effect of wastewater on properties of concrete. Journal of Building Engineering. 21. 106–112.

[56] Sayago, U.F.C. (2021). Design and development of a biotreatment of E. crassipes for the decontamination of water with Chromium (VI). Scientific Reports. 2021, 11- 9326.

[57] Sayago, U.F.C.; Ballesteros Ballesteros, V. (2023). Development of a treatment for water contaminated with Cr (VI) using cellulose xanthogenate from E. crassipes on a pilot scale. Scientific Reports.13- 1970.

[58] Abushanab, A.; Alnahhal, W. (2022). Performance of sustainable concrete incorporating treated domestic wastewater, RCA, and fly ash. Construction and Building Materials.329- 127118.

[59] Yadav, D at.al. (2021). Environmental and health impacts of contaminants of emerging concerns: Recent treatment challenges and approaches. Chemosphere. 272- 129492.

[60] Ghrair, A.M.; Al-Mashaqbeh, O. (2016). Domestic Wastewater Reuse in Concrete Using Bench-Scale Testing and Full-Scale Implementation. Water. 8- 366.

[61] Manjunatha, M.; Dhanraj, M.R. (2017). An Experimental Study on Reuse of Treated Waste Water in Concrete—A Sustainable Approach. International Journal of Engineering Research and Applications. 2.124–132.

[62] Rahman, M.M et.al. (2019). Sustainable Water Use in Construction. Sustainable Construction Technologies: Life-Cycle Assessment. Chapter 8. 211–235.

[63] J.-C. Zheng, et.al. (2009). Removal of Cu (II) in aqueous media by biosorption using Eichhornia Crassipes roots as a biosorbent material, Journal of Hazardous Materials. 171. 780–785.

[64] Kankia, M. U., et.al. (2021). Optimization of Cement-Based Mortar Containing Oily Sludge Ash by Response Surface Methodology. Materials, 14- 6308.

[65] Kankia, M. U., et.al. (2021). Performance of Fly Ash-Based Inorganic Polymer Mortar with Petroleum Sludge Ash. Polymers, 13- 4143.

[66] ASTM C876-15(2016). Standard Test Method for Corrosion Potentials of Uncoated Reinforcing Steel in Concrete. ASTM International: West Conshohocken, PA, USA.