Research Article

International Journal of Advanced Technology and Engineering Exploration, Vol 10(109)
ISSN (Print): 2394-5443 ISSN (Online): 2394-7454
http://dx.doi.org/10.19101/IJATEE.2022.10100384

Integrated method for waste water treatment using water hyacinth and its application in concrete

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Received: 21-December-2022; Revised: 02-December-2023; Accepted: 05-December-2023

Abstract
This research emphasizes the critical role of water quality in concrete construction, with a specific emphasis on utilizing treated wastewater from wetlands. The study employs a dual-stage treatment process involving charcoal and aggregate layers for primary treatment and water hyacinths for secondary treatment. The unique aspect of the study lies in investigating water hyacinths' capacity to absorb nutrients and contaminants from wastewater, providing a potential solution for soil and water remediation. Water hyacinths, particularly their stems and leaves, have proven effective as indicators of heavy metal pollution in tropical regions, acting as a natural filter to extract pollutants from wastewater. The primary objective of this investigation is the removal of heavy metals from wastewater, enabling the use of treated water in concrete production at varying proportions: 20%, 40%, 60%, 80%, and 100%. Additionally, the study incorporates silica fume at a concentration of 15% to enhance the concrete's durability and resistance. Concrete specimens were meticulously prepared and subjected to mechanical property evaluations, with a comparison to conventional M20 grade concrete. The results indicate a notable enhancement in the mechanical properties of the concrete, particularly when utilizing 80% of the treated wastewater in the concrete mix. The dual-stage treatment process, involving charcoal, aggregate layers, and water hyacinths, effectively removed heavy metals from the wastewater. The incorporation of silica fume at 15% concentration contributed to the concrete's improved durability and resistance.

Keywords
Eichhornia crassipes, Wetland, biological treatment, Charcoal, Heavy metal, Silicafume, Compressive strength, Flexural strength, Split tensile strength.

1.Introduction
Water scarcity has become a big problem in the world today. In the current situation, water resources need to be protected. In addition, many advanced technologies have been developed to clean and recycle the generated wastewater. The circulating water is stored in the tank and used as needed. Wastewater discharges pose a serious threat to ecosystems around the world. Water pollution is becoming a serious problem. Industrialization and civilization are major factors in wastewater production, which pollute the environment. Rapid population growth is also an important factor in this phenomenon.

This research focuses on reducing societies wastewater and water needs. In the future, water will be the main need for buildings and construction sites. It revealed the influence of wastewater and waste slurry on the strength and durability of the concrete specimens. Specific changes in compressive strength (CS), flexural strength, and other mechanical properties [1].

The utilization of carbonized water hyacinth for enhancing phase change energy storage materials. The effectiveness of water hyacinth in encapsulating and improving the thermal conductivity of these materials, offering potential benefits in energy-efficient building design [2]. Developing biomaterial fillers using eggshells, water hyacinth fibers, and

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banana fibers for green concrete construction [3]. A sustainable approach to thermal insulation by creating boards from wheat bran and banana peels. This innovative method offers an environmentally friendly solution for repurposing agricultural waste into construction materials, contributing to the growing field of sustainable building practices [4]. A water footprint analysis to assess the environmental impact, emphasizing the importance of incorporating regional architectural traditions into contemporary construction for sustainability [5]. The efficient separation of concrete waste into high-quality recycled aggregate, active recycled powder, and new concrete. The use of heat-mechanical synergistic treatment showcases a promising technique for recycling concrete and reducing the environmental footprint of construction materials [6].The mechanical properties of recycled aggregate concrete derived from waste concrete treated at high temperatures. This research contributes valuable insights into the structural performance and durability of concrete produced from recycled materials, offering potential solutions for sustainable construction practices [7]. The use of agricultural waste ashes (olive, rice husk, sugarcane leaves) to enhance ultra-high-performance concrete. This aligns with the trend of incorporating waste materials for sustainability, contributing to advancements in durable and eco-friendly concrete formulations. It emphasizes multi-waste stream utilization for improved concrete properties, reflecting a broader commitment to sustainable construction practices [8]. It explores the potential use of a natural material in concrete mixtures, possibly for enhancing certain properties or promoting sustainability in construction practices [9]. The utilization of water hyacinth (Eichhornia crassipes) for wastewater treatment in a residential setting. The relevance lies in understanding the environmental aspects and potential benefits of incorporating such treated wastewater into concrete production [10].

Water is the most important consideration at construction sites. The properties of fresh concrete and hardened concrete change with water. Before applying concrete, it is necessary to check the mineral properties of the water. This research focuses on the reduction of wastewater generated by society and the treatment of wastewater for various uses. The objective of this study is to use water hyacinth (Eichhornia Crassipes) as a bio-filter and to observe the potential of water hyacinth to remove pollutants in wastewater. The effect of wastewater type on concrete properties, provides valuable insights into the role of wastewater composition in influencing the characteristics of concrete [11].

The use of treated wastewater for concrete mixing, the practical application of treated wastewater in concrete production is essential for sustainable water management practices in arid regions [12]. The stability of cemented dried water hyacinth for biosorption of radionuclides. Examining the interaction between water hyacinth and cement under different circumstances, it shows the light on potential applications in nuclear waste management [13]. The compressive behavior of low-strength concrete confined with water hyacinth and jute non-woven fiber-reinforced polymer (NFRP), it explores innovative ways to enhance the mechanical properties of concrete [14]. The broader context of water hyacinth invasion is crucial for formulating strategies to address its challenges and harness its potential benefits [15]. The phytoaccumulation of heavy metals by water hyacinth, proposing a sustainable approach for industrial wastewater treatment. It signifies the potential of water hyacinth as a natural and efficient means to extract heavy metals from industrial effluents, contributing to the field of phytoremediation [16].

The effect of the treatment process is the biological treatment and removal of heavy metals from the contaminated water. The contribution of charcoal is an initial removal of dirty minerals which removes odor and color from contaminated water. The findings of the wastewater treatment reveal that the treated water can be utilized for concrete construction and other applications.

This paper is organized as follows: Section 2 covers the literature review. Section 3 explores into the methodology. Results and discussion are covered in Section 4. Finally, the paper concludes in Section 5.

2.Literature review

A comparative analysis of water hyacinth (Eichhornia crassipes) and water lettuce (Pista stratiotes) in preventing nutrient build-up in municipal wastewater. The study addresses the efficacy of these aquatic plants in mitigating nutrient pollution, highlighting their potential role in sustainable wastewater management practices [17]. Exploring the phytoremediation of industrial mines wastewater using water hyacinth. It underscores the application of water hyacinth in remediating polluted water from industrial sources, demonstrating its ability to absorb and mitigate contaminants in diverse industrial settings [18]. By removing organic matter and key nutrients such as nitrogen and phosphorus from wastewater, the harmful effects of wastewater pollution can be reduced. Many existing treatment technologies have been developed for wastewater treatment. However, these techniques have a greater scope of work and sustainability factors. Natural organic compounds, taste, odor compounds, and manufactured organic chemicals are all adsorbents of activated carbon, which are extensively utilized in drinking water [19, 20]. Activated carbon is an effective adsorbent because it is a porous material and provides a large surface area where pollutants can be adsorbed. In addition, to remove dissolved organics, turbidity, chlorine, sediments, volatile organic compounds, odors, and stabilization were also removed. Water hyacinths (Eichhornia crassipes) are floating aquatic plants adapted to wetlands made for wastewater treatment. These plants have a unique ability to treat wastewater by absorbing nutrients and other substances from the water, thus reducing the level of pollution. Water hyacinth roots play an active role in wastewater treatment. Extraction of plant pollutants occurs mainly through the root system. The root system is the main mechanism for preventing the toxicity of pollutants. The rich surface is provided by the veins that absorb and accumulate contaminants [21]. Plants can be used to remove a wide variety of pollutants, such as metals, pesticides, explosives, and oils. Different plants use biological processes and physical treatments, such as phytoremediation, to treat different pollutants [22].

Many wastewater treatment technologies have been developed and implemented over the years, with physical, chemical, and biological methods being the most common. However, most of the problems with these methods are high installation costs, operational and maintenance issues, and the effectiveness of the methods. Most procedures require complex machines and complex setups and cover a large area. This has become an environmental issue in the economy. Therefore, there is an urgent need to develop a cost-effective method of wastewater treatment. Water hyacinth, also known as water hyacinth is a promising plant that is used to address all of these issues [23]. Water hyacinth is biodegradable, with stiff leaves, spongy swelling stalks, and hairy roots that form enormous clumps. The ability to absorb heavy metals and minerals from wastewater has been a key factor. A large fibrous root system quickly absorbs chemical waste in wastewater and reduces the waste concentration by up to 100 times [24]. Water hyacinths can remove coliforms from wastewater and lower water's chemical oxygen demand (COD) [25]. As a result, water hyacinth can be utilized to treat industrial wastewater as a biological adsorbent. According to studies, this weed can be used as a raw material for aquaculture, biogas, and fertilizers when grown under regulated conditions. 95.5 percent water, 0.04 percent nitrogen, 1.0 percent ash, 0.06 percent P_2O_5, 0.20 percent K_2O, and 3.5 percent organic matter are all found in fresh plants [26, 27]. Nowadays, water hyacinth is used to purify wastewater all over the world. During the treatment process, it is recommended that wastewater be used for irrigation and aquaculture [28]. Aquaculture, biogas production, cow feed, waste manure, wastewater treatment, and industrial raw materials were all explored [29].

A comparison study of aquaculture wastewater filtration utilizing hyacinth, lettuce, and parrot feathers was studied [30]. The plant was subjected to study whether it can extract nutrients from aquaculture effluent. Aquatic plants have been shown to lower the number of contaminants in aquaculture effluent within two hours. They were able to confirm that wastewater recycling is applicable to aquaculture. The 28-day experiment was conducted in natural settings in a controlled atmosphere in a shielded room [31]. Biochemical oxygen demand (BOD) and COD levels decreased from 900 mg/l to 460 mg/l and 1424 mg/l to 766 mg/l, respectively. The nitrogen and phosphorus contents increased by 77.5 percent and 63.3 percent, respectively, while the pH decreased from 8.58 to 7.81. Crop sludge is abundant and is used as a bio-fertilizer, according to this study. The final wastewater following hyacinth treatment can be used for agriculture and fishing or recycled into rivers for purposes other than beverages, according to World Health Organization (WHO) regulations. Roots are particularly good at removing heavy metals [32]. The bio-adsorption capabilities of water hyacinth during metal recovery from aquatic environments were examined [33]. It discusses the uptake dynamics of a classical and competitive model, the physical and chemical treatment for hyacinth metal removal, and the effects of pH, temperature, initial metal concentration, and bio-absorbents.

Hyacinths' significance in wastewater remediation was examined [34]. They used wastewater samples from three distinct sectors to generate water hyacinth in a simple five-week experiment. Total suspended particles, BOD, dissolved oxygen (DO), nitrate nitrogen, cadmium, and iron were all found to be removed on an average basis. According to the researchers, water hyacinth can greatly lower a load of pollutants in textile, metallurgical, and pharmaceutical wastewater when compared to the removal of BOD, DO, total suspended solids (TSS), nitrogen, and cadmium, but not copper and iron. Pharmaceutical wastewater showed the largest decrease, followed by metallurgy and textile wastewater. They believe that the hyacinths of the study were more effective at removing cadmium and less effective at removing copper and iron. The use of water hyacinth waste for producing fiber-reinforced polymer composites for concrete confinement, it evaluates the mechanical performance and environmental implications [35]. It also goes into the different models' absorption rates, the factors that affect bioabsorption capacity, and the effects of physical and chemical changes in hyacinth on wastewater. Laboratory experiments on wastewater to reduce COD levels through bioremediation techniques using water hyacinth (Eichhornia Crassipes) [36, 37]. The outcomes of the treatment were found to be within the National Environmental Standards and Regulatory Enforcement Authority's limits (NESREA). The impact of recycled aggregates and treated wastewater on concrete under different exposure conditions, it explores the potential of incorporating sustainable materials in concrete construction [38, 39]. The concentrations of dissolved solids, suspended solids, turbidity, COD, and BOD in the water were all dramatically reduced.

Understanding the practical aspects of incorporating wastewater in concrete production is crucial for sustainable construction practices [40]. The effect of wastewater on concrete properties, this study provides valuable insights into the challenges and opportunities associated with incorporating wastewater in concrete mixes. Understanding the impact on concrete properties is essential for ensuring the durability and structural integrity of constructions [41]. The perspectives of phytoremediation using water hyacinth for the removal of heavy metals and pollutants in wastewater. It sheds light on the broader environmental applications of water hyacinth, linking its potential in phytoremediation to the removal of contaminants in water [42]. The effect of using wastewater on high-strength concrete properties, this provides insights into the practical implications of incorporating wastewater in concrete production [43]. The properties of concrete produced with treated wastewater, it is contributes to understanding the feasibility and potential challenges associated with incorporating treated wastewater in construction materials [44]. The performance of concrete incorporating ground granulated blast furnace slag (GGBS) in aggressive wastewater environments, this study provides insights into the durability of concrete in challenging conditions [45]. The incorporation of water hyacinth ash into concrete to develop a sustainable building material [46]. It could provide valuable insights into the potential advantages and challenges associated with utilizing water hyacinth in construction materials, contributing to the broader understanding of sustainable and innovative construction practices [47].

2.1Review analysis

2.1.1Wastewater treatment using water hyacinth

The study begins by comparing the efficacy of water hyacinth and water lettuce in preventing nutrient build-up in municipal wastewater. Subsequently, it delves into the phytoremediation of industrial mines wastewater using water hyacinth, showcasing its capability to absorb and mitigate contaminants in diverse industrial settings. The removal of organic matter and key nutrients like nitrogen and phosphorus from wastewater is emphasized, contributing to the reduction of harmful effects associated with wastewater pollution.

2.1.2Challenges with traditional wastewater treatment methods

The literature points out the limitations of traditional wastewater treatment methods, citing high installation costs, operational challenges, and large spatial requirements. This creates an environmental concern, necessitating the development of cost-effective alternatives.

2.1.3Water Hyacinth's role in wastewater treatment

The significance of water hyacinth in wastewater remediation is extensively explored. The plant's biodegradability, fibrous root system, and ability to absorb heavy metals and minerals from wastewater are highlighted. Studies demonstrate its effectiveness in reducing concentrations of contaminants such as coliforms, BOD, COD, nitrogen, and phosphorus.

2.1.4Applications beyond wastewater treatment

Beyond wastewater treatment, the review covers various applications of water hyacinth, including its potential use as raw material for aquaculture, biogas production, and fertilizer. The plant's adaptability for use in aquaculture, its role as a biofilter for domestic wastewater treatment, and its incorporation into concrete for sustainable building materials are discussed.

2.1.5Eco-friendly and sustainable solutions

The review consistently emphasizes the eco-friendly nature of water hyacinth-based wastewater treatment. Its ability to improve water quality, address specific industrial pollution challenges, and contribute to biomass production in floating systems underscores its potential for widespread adoption in sustainable and eco-conscious wastewater management practices.

2.1.6Design considerations and long-term effectiveness

The literature touches upon design considerations for water hyacinth-based systems in constructed wetlands, highlighting their potential to enhance the efficiency of such systems for eco-friendly wastewater treatment. Long-term studies showcase the effectiveness of water hyacinth beds in improving water quality in urban canals.

2.1.7Incorporation into building materials

The final section introduces an innovative application of water hyacinth ash in concrete, indicating its potential to influence concrete properties and contribute to the development of sustainable building materials.

2.2Experimental setup

Treated wastewater is collected from wetlands after undergoing the dual-stage treatment process involving charcoal and aggregate layers for primary treatment and water hyacinths for secondary treatment. Ordinary Portland cement (OPC) is used as the binding agent. Fine aggregates, meeting the required specifications for concrete production. Silica fume, a highly reactive pozzolanic material, is included in the concrete mix at a concentration of 15%. Different proportions of treated wastewater (20%, 40%, 60%, 80%, and 100%) are used as a replacement for conventional mixing water in the concrete mix. A concrete mixer with a known mixing capacity is used to prepare the concrete batches. The mixing process should be consistent to ensure uniformity. Concrete specimens are cast in molds of standard dimensions, such as cubes, cylinders and prism, to facilitate testing. The concrete specimens are cured under controlled conditions, typically at a specified temperature and humidity, to simulate real-world curing conditions for concrete. Testing apparatus for properties like CS, tensile strength, flexural strength, and density are employed as per standard testing procedures. The mechanical properties of the concrete specimens are measured and recorded for each mix proportion. Statistical analysis is performed to compare the mechanical properties of the concrete specimens using treated wastewater at varying proportions with those of conventional M20 grade concrete. The results are interpreted to determine the optimal proportion of treated wastewater and the effectiveness of the water hyacinth-based secondary treatment in enhancing the concrete properties.

3.Methods

3.1Material used

Eichhornia Crassipes (Water Hyacinth) is a floating aquatic plant with two distinct morphologies, and intermediates depending on growing conditions. Water hyacinths are typically harvested from natural water bodies, such as ponds or rivers. It's essential to collect healthy plants free from diseases or contamination. Eichhornia Crassipes (*Figure 1*) are bluish-purple, large, fresh, and lush in appearance. Water hyacinth has the appropriate ability to remove pollutants in domestic wastewater. Specific objectives are detailed in the principles for supporting domestic Wastewater purification. Before use, water hyacinths should be thoroughly cleaned to remove any adhering contaminants or impurities. This can be achieved by rinsing the plants with clean water. Silica fume is an ultrafine powder collected from the by-product of silicon and ferrosilicon alloys and composed of spherical particles (*Figure 1*). It is a fine concrete particle. It should be handled with care to prevent inhalation. It should wear appropriate personal protective equipment (PPE) like masks and gloves. Which can reduce thermal cracking induced by the concrete's hydration heat and increase the concrete's resistance to acid waste erosion. The mechanical qualities of concrete can be improved by using it. Charcoal is made by burning wood and other organic matter in a low-oxygen atmosphere. By removing water and other volatile elements, the resulting charcoal is burned at high temperatures with little or no smoke. Charcoal can be derived from various organic materials, like wood, coconut shells. It should be collected from the south zone. Charcoal used in the primary treatment process should be of high quality and free from any contaminants. Activated charcoal, which has a high surface area for adsorption, may be preferred. Charcoal particles may need to be of a specific size or granularity. If so, sieves or screening equipment can be used to ensure uniformity. Coal is a poor heat and electrical conductor (see *Figure 1*). With no electrons circulating freely, amorphous carbon atoms are grouped in an amorphous, irregular condition. The low thermal and electrical conductivity of coal is due to this. Depending on the density of the wood used as raw material, the density ranges from 0.2 to 0.6 t/m3. The bulk density of coal depends on the bulk density and grain size distribution and is from 180 to 220 kg/m3. Raw wastewater samples (*Figure 1*) were collected daily from a nearby urban sewage treatment plant (VEI., Tamil Nadu, India) for performance evaluation. Samples and 10 water quality parameters (pH, COD, BOD, DO), TSS, total nitrogen (TN), and ammonia nitrogen (NH3-N)) were collected every 24 hours intervals. Performance cement has a specific gravity of 3.15, an initial setting time of 35 minutes, a total setting time of 270 minutes, and a consistency of 32 percent when made using OPC grade 53. These materials are handled following standard concrete mixing procedures. Cement is usually stored in a dry place to prevent moisture absorption. Use natural crushed stone (size 20mm) with a specific gravity of 2.65, a water absorption rate of 0.45%, and a coarse aggregate fineness coefficient of 1.20. Coarse aggregates were verified according to Indian Standard Specification IS 383-1970. Physical properties of the materials as shown in *Table 1*. The maximum particle size of fine aggregate (M-sand) is 4.75mm, the specific gravity is 2.54, the water absorption rate is 1.35%, and the particle size coefficient is 2.21. Domestic waste water were collected from the urban sewage treatment plant. Big cane (20liter capacity) was used to collect the waste water from treatment plant. Wear appropriate PPE, including gloves and lab coats, when collecting samples to ensure safety and prevent contamination. Use clean, sterile containers for sample collection. Collect a representative sample by taking multiple grab samples or using a composite sampler over a specific time interval. This helps account for variations in wastewater composition. Record essential metadata for each sample, including the date and time of collection. Collected samples cannot be analyzed immediately, store them in a cool environment to slow down biological and chemical reactions.

Figure 1 Photocopy of materials used

Table 1 Physical properties of raw material

Physical properties	Cement	Fine aggregate	Coarse aggregate	Silica fume
Specific gravity	3.13	2.21	2.65	2.23
Color	Dark grey	Light grey	Blackish	White
Loose bulk density (kg/m^3)	1332	1210	-	580
Loss on ignition (LOI) (%)	3.12	0.48	-	0.51

3.2Waste water treatment

Wastewater is not sent directly to water hyacinths. First, the wastewater is diverted to pretreatment. This is the initial step where wastewater is collected from various sources, such as households, industries, and municipal sewer systems. The collected wastewater may contain a mixture of organic and inorganic contaminants, suspended solids, nutrients, and other pollutants. Primary treatment is the first stage of physical and chemical treatment to remove large, suspended solids and reduce the organic load in the wastewater. In this process, the wastewater flows through a series of layers. Charcoal is used to adsorb organic compounds and certain chemicals from the wastewater. It can help remove odors and color as well. The next layer of aggregate is typically consisting of larger particles like gravel or crushed stone. Its primary function is to act as a physical barrier to remove large debris and sediments from the wastewater and final layer of primary treatment using sand. This layer consists of smaller particles, often sand, which helps in further trapping and settling smaller suspended solids. The arrangement of these layers allows for the gradual settling of solids, adsorption of organic compounds, and the removal of some impurities from the wastewater. Primary treatment conditions may involve some mixing and aeration to aid in the settling and separation of solids (*Figure 2*). Secondary treatment is the biological treatment stage that follows primary treatment. It is focused on further removing organic matter, nutrients (like nitrogen and phosphorus), and other contaminants from the wastewater. In this case, water hyacinth (Eichhornia crassipes) is used as the treatment agent. Water hyacinth is a floating aquatic plant known for its ability to absorb and metabolize nutrients and organic pollutants from water. Water hyacinth typically grows on the surface of the wastewater, and its roots and foliage provide a habitat for beneficial microorganisms that break down organic matter. The treatment conditions for water hyacinth include maintaining suitable water quality parameters such as temperature, pH, and nutrient levels to support its growth and pollutant removal capabilities. To measure the level of pollution (decontamination efficiency) and the quality of water treatment, wastewater samples were tested before and after treatment using multiple criteria (physicochemical and biological). pH, colour, odor, total dissolved solids (TDS), TSS, BOD, COD, chlorides, and nitrates are among the parameters studied. Analysis of heavy metals in wastewater samples treated from constructed wetlands using Eichhornia Crassipes (*Figure 3*).

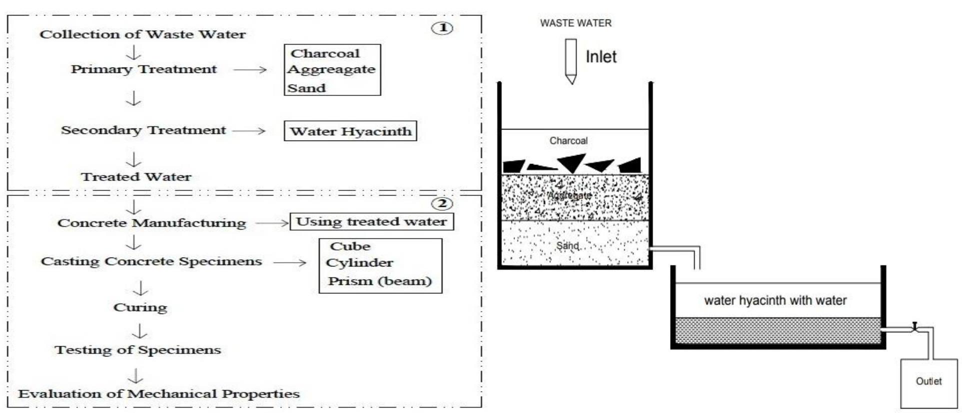
Eichhornia Crassipes is a high-performance strengthening treatment agent for domestic sewage treatment. The treatment efficiencies of the water quality metrics studied, such as pH, DO, BOD, COD, nitrates, chlorides, TS, TDS, TSS, and heavy metals. The treated sample was observed to be clear and odorless in color and odor. The pH value before and after treatment depends on the dilution group. The results of all serial dilutions were close to neutral in *Table 2.*

The pH was 8.6 before treatment and 7.4 after treatment at 100 percent dilution. The pH value of the wastewater, according to the Central Pollution Control Board of India's wastewater guidelines, is 6.5-7.5, which is the result of all treatment tests. The amount of DO changed after various dilutions of hyacinth water treated the wastewater. If the wastewater is not diluted, it contains a lot of organic and inorganic substances, so the DO content in the wastewater is low and a foul odor is formed. However, the amount of DO increased after treatment. The 100% diluted OD was 0.5 before treatment and 4.1 mg / L after treatment. DO levels increased after treatment in all series of wastewater dilutions. Estimated TDS, TSS, and Total Solidshow that polymerization is increased. Dilution to 100% produced the greatest reduction in solid content. Before and after processing, BOD was calculated from the samples. The BOD was 230 mg/L after 100 percent of dissolving the wastewater, but it was lowered to 130 mg/L after 100 percent of dissolving the wastewater. Hydraulic retention time (HRT) affects the BOD removal efficiency. Longer hormone replacement therapy can improve interactions within the aquatic plant system, resulting in increased organic matter production and processing efficiency. All of the dilution series had distinct COD levels before and after treatment. It fell from 315 mg/L before COD treatment to 155 mg/L after treatment at 100 percent dilution.

Table 2 Waste water physicochemical parameters before and after treatment with Eichhornia Crassipes

Parameters	pH		DO mg /L		TSS mg /L		TDS mg /L		TS mg /L		BOD mg /L		COD mg /L		NO_3 mg /L		Chlorides mg /L	
	*B.T	*A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
Waste water	8.6	7.8	0.5	4.1	1920	945	1240	620	3160	1610	230	130	315	155	9.2	1.21	44.02	35.80

* Before treatment (B.T.) and After treatment (A.T.)



(a) (b)

Figure 2 (a) Methodology and (b) Wetland treatment process

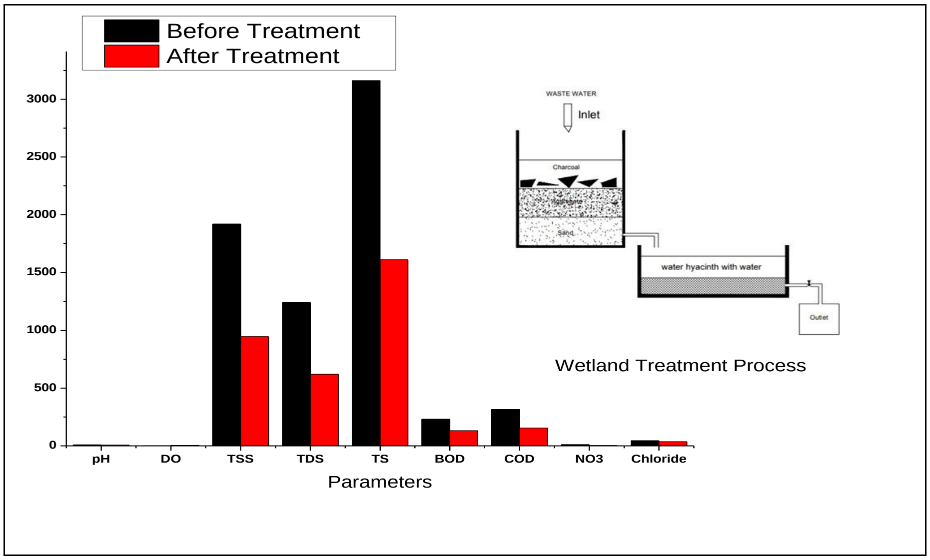


Figure 3 Physiochemical parameters of the treated waste water

Nitrate concentrations vary based on dilution. A dilution of 100 percent is the most drastic decrease. The results of studying the treated wastewater suggest that it can be utilized for agriculture, laundry, gardening, planting, and other uses. *Table 3* depicts the heavy metal removal from wastewater before and after treatment. This plant has been studied and reported to be suitable for wastewater treatment. The experiment was conducted in a semi-continuous wastewater drain tank with or without water hyacinth. *Figures 4* and *5* show how heavy metals were removed from wastewater before and after treatment. The removal efficiencies of metals in the plant parts after treatment, using the following formula (Equation 1),

$$\text{Removal Efficiency (\%)} = ((\text{Metal Concentration Before Treatment} - \text{Metal Concentration After Treatment}))/(\text{Metal Concentration Before Treatment}) \times 100 \quad (1)$$

Hyacinth wetlands are highly effective at removing 70% BOD, 68% COD, 41%TS, 100% zinc, 30% nitrate, 38% chloride, and 94% sulphate from wastewater. The removal efficiency of metal is calculated using the Equation 1.

3.3Mix design and test methods

The strength of M20 grade concrete obtained in this investigation is IS: 456-2000, and the CS reaches 20N/mm2. Several tests were performed for designing mixtures of different amounts of treated water. Flow rates of 140 ± 20 mm were obtained according to the test method using different proportions of water treated with a plasticizer. Purified water was replaced with treated water at 0%, 20%, 40%, 60%, 80%and 10%levels. The remaining 15% silica fume is always mixed in all M20 concrete mixes. *Table 4* shows the amount of material in kilograms used to make one cubic meter of concrete.

The number on the mix identification indicates the cement replacement rate. In fresh concrete conditions, SCC emits cubes, cylinders, and prismatic specimens to contain and control the properties of fresh concrete, and to enforce the mechanical properties of concrete. After treatment for 7 days, 14 days, and 28 days, the mechanical properties were evaluated and compared with the performance of the control concrete.

Table 3 Metal analysis of Eichhornia Crassipes plant sections

Metals	**Metals before treatment in the plant parts (mg)**	**Metals after treatment in the plant parts (mg)**	**(%) Efficiency**
Cu	2.054	2.527	23.50
Ni	0.209	0.223	6.70
Co	0.028	0.052	85.71
Fe	0.155	0.206	32.90

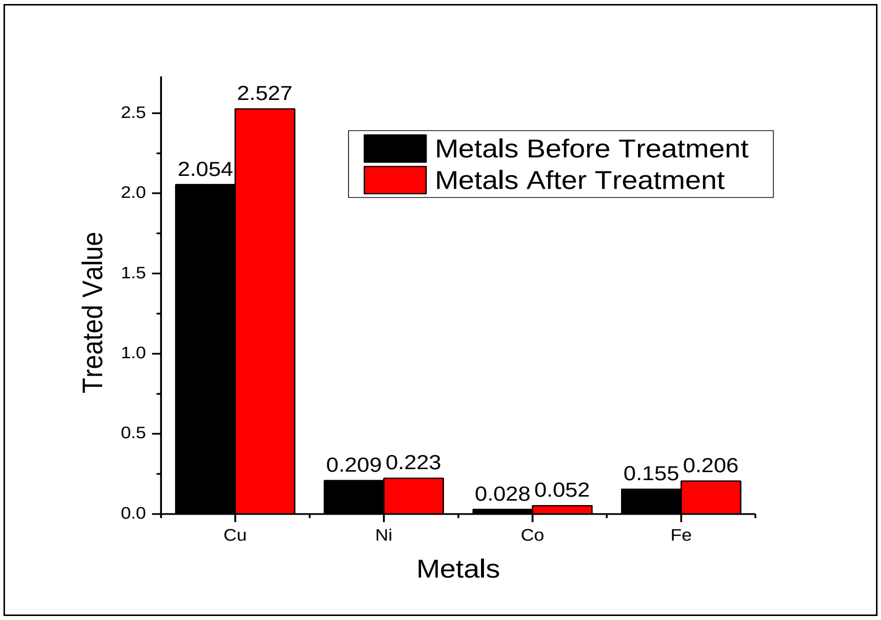


Figure 4 Before and after treatment of heavy metal removal in waste water

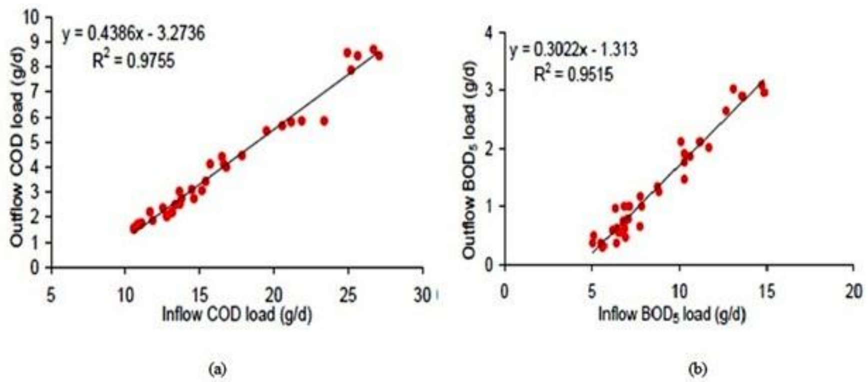


Figure 5 (a) Relationship between COD (b) and BOD5 inflow and outflow

Table 4 The amount of materials required to produce 1 cubic meter of concrete (kg)

Mix ID	Normal water (liter)	Treated Water	Powder content (kg/m^3)		Aggregate (kg/m^3)	
			Cement	Silica fume	Fine aggregate	Coarse aggregate
0TW*	141	0	403	0	706	1302
20TW	112.8	28.2	342.55	60.45	706	1302
40TW	84.6	56.4	342.55	60.45	706	1302
60TW	56.4	84.6	342.55	60.45	706	1302
80TW	28.2	112.8	342.55	60.45	706	1302
100TW	0	141	342.55	60.45	706	1302

*TW – Treated water

4.Results and discussion

After pouring all the samples, check the mechanical properties of the concrete. This is a very important factor before incorporating the sample polymerization process. During polymerization, the temperature was maintained at 27 ± 20 ° C. CS was assessed according to BIS 516. Strengths were cured over 7 days, 14 days, and 28 days. The test strength was the average of the three specimens, and CS, split tensile strength, and flexural strength was evaluated. *Figure 6* shows the morphological image scanning electron microscopy (SEM) of the treated concrete.

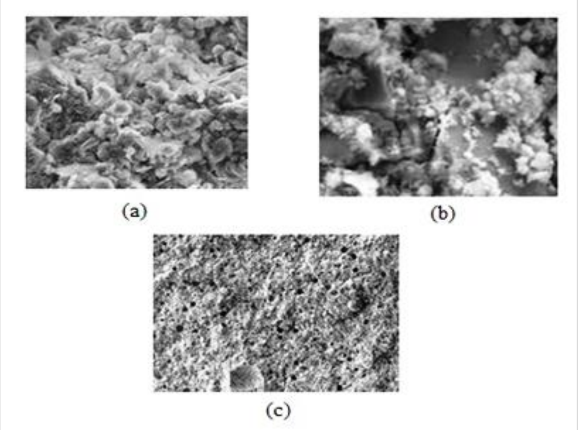


Figure 6 (a) SEM image of CSH gel formation, (b) SEM image of crack formation, (c) SEM image of voids developed

Cubes are cast and cured under specific conditions (temperature and humidity) for the desired curing duration (7 days, 14 days, 28 days).After curing, the specimens are placed in a testing machine, and a gradually applied axial load is applied until the specimen fails. The maximum load at failure is recorded, and the CS is calculated as the maximum load divided by the cross-sectional area of the specimen.

The CS test was performed in 7, 14, and 28 days, as shown in *Figure 7*. The CS of conventional concrete were 13.51 MPa, 18.28, and 23.68 MPa on days 7, 14, and 28 of the hardened specimens, respectively. The CS of the combination of 60% treated water, 40% plain water, and 15% SF were 14.65 MPa, 19.12 MPa, and 24.82 MPa at 7, 14, and 28 days, respectively. These values show 8.4%, 4.5%, and 4.8% higher CS than conventional concrete at 7, 14, and 28 days of curing, respectively. The CS of concrete was increased with the addition of silica vapor to the concrete mix. Concrete mixtures mixed with 20-100% silica fume-treated water (15%) have been shown to slightly increase the CS of concrete compared to conventional concrete.

In particular, the silica fume resistance of concrete was increased by 60% compared to control concrete. Prismatic specimens (rectangular bars) are cast and cured under similar conditions as the CS specimens. The specimens are placed on a testing machine with a span length, and a load is applied at the center of the specimen until it fractures. The maximum load at failure is recorded, and the flexural strength is calculated based on the dimensions of the specimen. The flexural and split tensile strengths of 80TW concrete are improved compared to conventional concrete. When the flexural strength of 60TW is gradually increased, the nominal flexural strength of M20 concrete (4.21N/mm^2) is reached, and the tensile strength value of 60TW concrete also reaches the standard value of concrete. *Figures 8* and *9* are shown the flexural properties and cracking strength of water-treated concrete. The optimal ratio of concrete mixture to M20 grade water crushing is 80 TW.

The split tensile strength of concrete is a measure of its ability to resist tensile stresses along a plane perpendicular to the direction of loading. It is an essential property, especially in situations where concrete is subjected to bending or flexural stresses. Cylinders are cast and cured under the same conditions as the CS specimens. After the curing period, the cylindrical specimen is placed horizontally between two steel bearing plates in a testing machine. A compressive load is applied along the axis of the cylinder, causing it to rupture along the horizontal plane. The applied load creates tensile stresses within the concrete specimen. The maximum load at which the cylinder fails (splits) is recorded.

The novelty of this study is the use of water hyacinth to treat wastewater, and the treated water is then used to increase concrete strength and decrease the demand for water during building. Using a plant, wastewater was pretreated in earlier publications. An existing study suggested that the processing of wastewater be done in order to improve the mechanical qualities of concrete.

4.1Implications and significance of the test results

CS is a fundamental property of concrete, and it is critical for assessing the concrete's load-bearing capacity. The conventional concrete showed increasing CS over time, which is a typical behavior as concrete continues to gain strength during the curing period. The concrete mixture with 60% treated water, 40% plain water, and 15% silica fume demonstrated higher CS compared to conventional concrete at all curing durations. This increase was 8.4% at 7 days, 4.5% at 14 days, and 4.8% at 28 days. The addition of silica fume to the concrete mix contributed to the improved CS. The concrete mixtures with silica fume-treated water exhibited slightly higher CS compared to conventional concrete.

The study found that the flexural strength of the concrete mix with treated water was improved

compared to conventional concrete. Specifically, the study noted that the flexural and tensile strengths of the concrete with 80% treated water were enhanced. The results indicate that the incorporation of treated water in the concrete mix can positively impact its flexural strength, making it more suitable for structural elements that experience bending stresses.
Split tensile strength measures a concrete's ability to resist tensile stresses along a plane perpendicular to the direction of loading. The study mentioned that the use of treated water in the concrete mix slightly enhanced its split tensile strength. This improvement is important in scenarios where concrete is subjected to tensile stresses, as it suggests that the concrete can better withstand cracking and tensile forces.

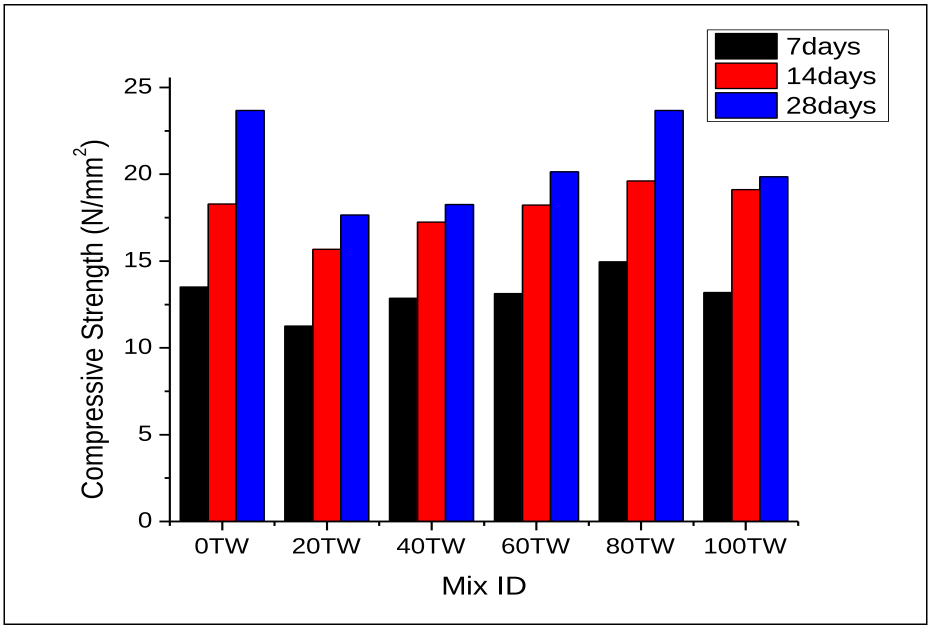


Figure 7 Variation of CS of concrete

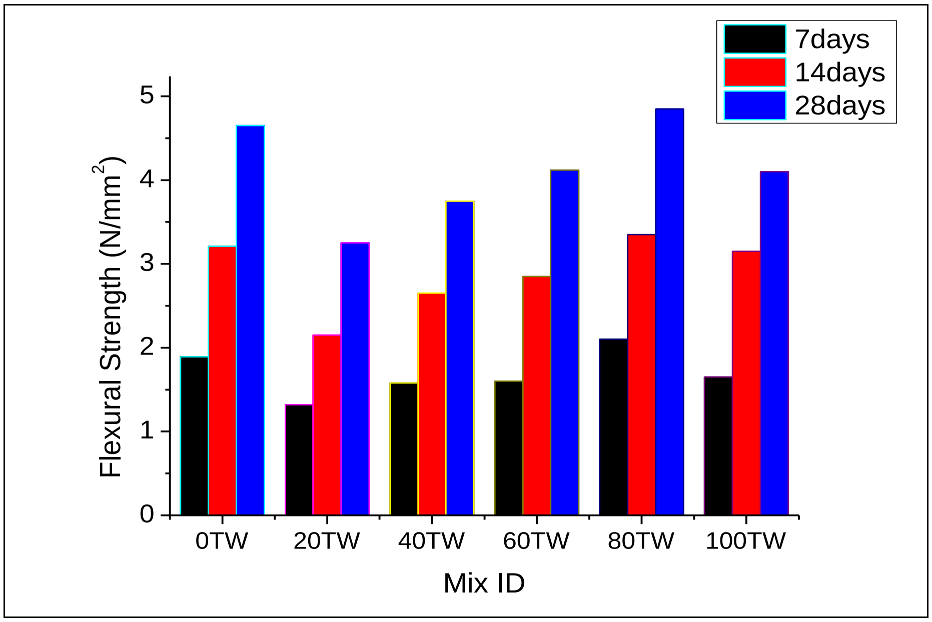


Figure 8 Variation of flexural strength of concrete

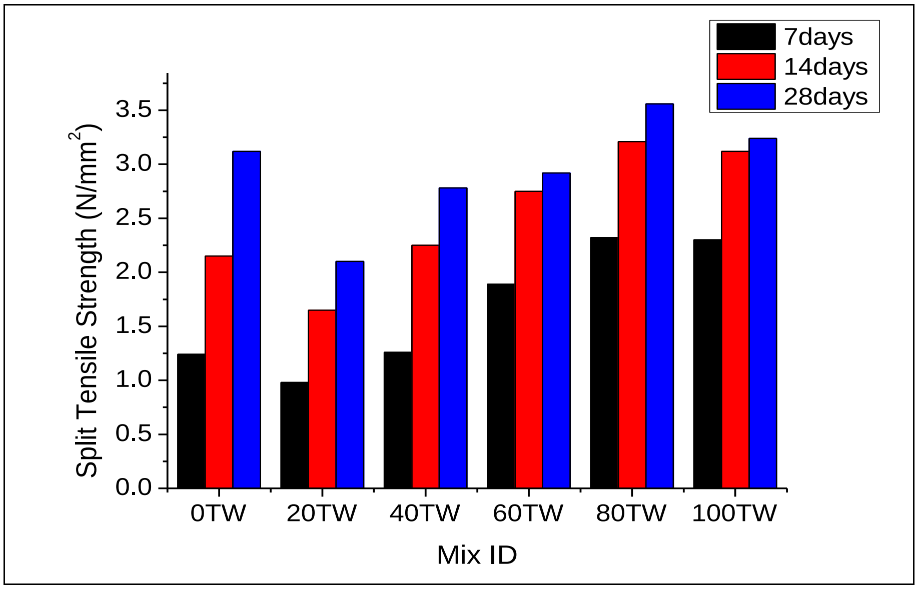


Figure 9 Variation of split tensile strength of concrete

The study's findings suggest that the incorporation of treated water, specifically water treated with water hyacinth, along with the addition of silica fume, can enhance the mechanical properties of concrete. The observed trends, where concrete with treated water exhibited improved compressive, flexural, and tensile strength, are significant for the construction industry. These enhancements can lead to the development of more robust and sustainable concrete mixtures. The use of water hyacinth as a treatment method for wastewater is innovative and environmentally friendly. It not only contributes to improving water quality but also reduces the demand for fresh water in concrete production. The study's findings align with the research objectives of evaluating the impact of treated water on concrete properties and mechanical strengths.

4.2Study limitations and comparison with other studies

Other species should be examined for treatment possibilities, as the author studied and built a wetland system for one plant species. Another disadvantage of this study was that it only looked at one season; however, plant performance can alter depending on the season. During construction, only treated water was used in the concrete. As a result, an entire year's worth of research is required.

In a prior study, water hyacinth was used to remediate the wastewater. Following that, agriculture uses treated wastewater. But two treatment methods are introduced in this study. Both primary and secondary treatment processes, using charcoal and aggregate layers and water hyacinth, were carried out. Large amounts of wastewater were processed during this process. In a very short amount of time, it is possible to remove polluted minerals and heavy metals from wastewater. After being treated, water was used in concrete mixtures and other construction projects. Only 40–50% of water was reported to be recovered during the water hyacinth treatment method in earlier research. The use of water hyacinth for wastewater treatment and subsequent incorporation of treated water into concrete aligns with the principles of environmental sustainability [2, 3, 15]. When treated water was incorporated into the concrete mix (80% treated water, 20% plain water, and 15% silica fume), the CS improved significantly. At 28 days, this mixture exhibited a CS of 24.82 MPa, which is approximately 4.8% higher than conventional concrete. This improvement in CS [14], observed enhanced concrete strength when treated wastewater was used in concrete production. This enhancement in flexural strength aligns with the broader literature on the use of supplementary materials and treated water to improve concrete properties. The potential for water hyacinth and its treated water to enhance the mechanical properties of concrete, including split tensile strength [13, 21]. According to these studies, treated water may be successfully collected up to 80% of the time and used in the concrete to increase the mechanical properties compared to conventional concrete.

4.3Discussion

4.3.1 Key findings summary

This study highlights the effectiveness of wetland treatment using water hyacinths for household and societal wastewater. Employing two distinct treatment processes, primary treatment addresses color, odors, and solid wastes, while secondary treatment utilizes water hyacinths for heavy metal removal, showcasing the versatility of the approach. The combined methods prove to be a practical and efficient strategy for comprehensive wastewater treatment. Treated water significantly enhances both fresh and hardened concrete properties, exhibiting improved workability, increased hydration rates, and enhanced compressive, flexural, and tensile strengths. The incorporation of 15% silica fume further bolsters concrete strength, aligning with established concrete technology practices. The study identifies the optimal mix proportion of 80% treated wastewater and 15% silica fume as most favorable for superior concrete performance.

4.3.2 Interpretations and implications

These findings affirm the potential of water hyacinth for sustainable wastewater treatment, offering a cost-effective and eco-friendly alternative. The combination of primary and secondary treatment ensures comprehensive pollutant removal, making treated water suitable for various applications, including construction. The positive impact of treated water on concrete properties supports resource-efficient construction practices, fostering the development of innovative and eco-friendly construction materials. The research underscores the significance of wetland-based treatment systems in mitigating wastewater pollution and promoting environmental sustainability. Utilizing treated water in construction can reduce the demand for freshwater resources, contributing to sustainable building practices.

4.3.3 Comparative study analysis

Although the study primarily focuses on M20 grade concrete and specific mix proportions, generalizing these findings to other concrete grades and mix designs may require further research and validation. Evaluating the water hyacinth-based wastewater treatment system's performance across different seasons could provide a more comprehensive understanding of its effectiveness. Additionally, assessing the long-term durability and performance of concrete produced using treated water is crucial for practical applications in construction. It is essential to consider potential ecological impacts and sustainability aspects of large-scale wetland systems.

4.3.4 Overall analysis of results

This research contributes to sustainable water management by showcasing the potential of water hyacinth-based treatment and its benefits for construction. It offers a valuable resource-efficient approach in line with the global shift towards sustainable and eco-friendly practices. Enhanced concrete properties with treated water open avenues for greener and more resilient infrastructure. The findings provide an innovative solution to wastewater treatment and construction challenges, emphasizing the importance of sustainable practices in urban development and construction where water resources are finite. The study's broad applications offer a pathway towards more environmentally responsible and resource-efficient construction methods.

Recommendations

Future research should assess the wetland system's performance throughout various seasons to capture seasonal variability. Expanding the study to include other concrete grades and mix designs would broaden the understanding of treated water applicability. Long-term studies on concrete durability are crucial for real-world applications. Conducting comprehensive cost-benefit analyses is necessary to evaluate the economic viability of implementing wetland-based treatment systems and treated water usage in construction. Environmental impact assessments should accompany large-scale wetland system deployments.

Limitations

Several limitations are acknowledged, including the focus on M20 grade concrete and specific mix proportions. Generalizing findings to other concrete grades and mix designs requires further validation. The short-term focus on treated water's effects on concrete properties necessitates investigations into long-term durability. Consideration of ecological impacts and sustainability aspects of large-scale wetland systems is vital. Further exploration of economic feasibility, including cost-benefit analyses, is necessary for practical implementation. A complete list of abbreviations is shown in *Appendix I.*

5.Conclusion and future work

Water treated with hyacinth in wet soil has good composition and achieves the proper workability of M20 grade concrete. Based on the resulting wastewater treatment and mechanical properties, the following conclusions are drawn.

- Wetland treatment using hyacinths to treat household and society wastewater is a successful method. Wetlands are easy to build up, and more wastewater is easy to decontaminate and chemically characterize, like pH, BOD, COD, DO, TSS, etc. were determined.

- This system is used in this research to remove the contaminated minerals from the wastewater. Two different methods of treatment process were used. In primary treatment process is very effectively acted as wastewater to remove color, odors, solid wastes, etc., secondary treatment process is used water hyacinth the effect of removing the heavy metals from the polluted water.
- The aquatic system of the water hyacinth plant can assist reduce pollution load from wastewater, enhance water quality, and the treated water can be used for concrete construction purposes.
- Treated water mix concrete that has been treated with water can improve the qualities of both fresh and hardened concrete. In the process of wastewater utilization after concrete treatment, the hydration process of concrete is increased. The addition of 15% silica fume, on the other hand, has been found to boost the strength of concrete.
- The workability of treated water concrete is 140mm it is recommended for concrete grade M20. Silica fume is mixed with concrete to increase its CS. The combination of treated water and concrete mixes of different silica fume (15%) produced better performance than conventional concrete.
- In fresh concrete, the performance is also better than in control concrete. The CS of 80TW and 15% silica vapor mixture is higher than control concrete in terms of CS, flexural strength, and breaking strength.

Finally, up to 80% of treated wastewater and 15% of silica fume were used in concrete. This proportion was obtained in the optimum value of concrete were achieved. A built wetland with a variety of plant species could be used in future experiments to improve treatment possibilities. For a better assessment of the plant throughout seasons, the performance of this combination should be evaluated for the entire year, i.e. during various seasons. Additionally, treated water can be used in a variety of construction applications due to its technical qualities.

Acknowledgment
The authors would like to thank Vivekanandha College of Technology for Women, Department of Civil Engineering for providing the laboratory test facilities. Special thanks to the Chairman and Secretary for their motivation and support. The authors greatly appreciate the reviewers and editors for their critical comments that helped in improving the quality of this manuscript.

Conflicts of interest
The authors have no conflicts of interest to declare.

Author's contribution statement
A Ananthakumar: Conceptualization, Methodology, Investigation, and Writing - Original draft, Derive the Numerical Analysis, Writing - review & editing. **Saravanan M M and Devi M**: Writing - review & editing, Supervision and Correction.

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Appendix I

S. No.	Abbreviation	Description
1	BOD	Biochemical Oxygen Demand
2	COD	Chemical Oxygen Demand
3	CS	Compressive Strength
4	DO	Dissolved Oxygen
5	GGBS	Ground Granulated Blast furnace Slag
6	HRT	Hydraulic Retention Time
7	LOI	Loss on Ignition
8	NH3-N	Ammonia Nitrogen
9	NESREA	National Environmental Standards and Regulatory Enforcement Authority
10	NFRP	Non-woven Fiber-Reinforced Polymer
11	OPC	Ordinary Portland Cement
12	PPE	Personal Protective Equipment
13	SEM	Scanning Electron Microscopy
14	TDS	Total Dissolved Solids
15	TN	Total Nitrogen
16	TSS	Total Suspended Solids
17	TW	Treated Water
18	WHO	World Health Organization