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Research Paper

Comparative study of floating wetland and constructed wetland for Automobile wastewater treatment

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Abstract

The wastewater from the automotive industries is one of the primary sources of oil and grease, heavy metals, cyanide, organic and inorganic pollutants that considerably adds to the pollution load of receiving water bodies and is vital for stream contamination. And also, nowadays automobile water treatment methods are highly energy demanding and expensive. In this study, the comparison of a floating and constructed wetland systems were carried out for finding, which is more effective in reducing the water quality parameters such as P^H, BOD, COD, TSS and TDS. The plant selected for the floating system and constructed wetland were *Eicchorniacrassipes* and *Eleusine indica* respectively. Analysis of the result indicates that the characterized constructed wetland is an effective secondary treatment method as compared to the floating wetland system, as latter resulted in increase of BOD & COD due to the desiccation of water hyacinth. During the implementation of a constructed wetland with a retention time of 15 days, it was shown to effectively maintain a neutral pH, reduce BOD by 87.17 %, COD by 88 %, and TSS by 77 %, making the water suitable for domestic purposes such as washing vehicles or cleaning the household. At the same time, the TDS increased by 5 % because of the presence of plenty of microorganisms and particles in the soil. Thus, a constructed wetland can be used as a sustainable form of water treatment method as it's not energy demanding, eco-friendly and only needs less maintenance.

Keywords: Automobile waste water treatment, Floating wetland, Constructive wetland, Eicchorniacrassipes, Eleusineindica, P^H, BOD COD, TSS, TDS.

Introduction

India is the fourth biggest automobile producer in the world, manufacturing an average of more than 4 million cars annually. Automobile workshops are an integral part of the service industry (Sathiya, M. P *et al.,* 2008). Since it serves an essential part in maintaining the vehicle's optimal condition. Due to fast economic and infrastructural expansion, the automobile population in India has expanded dramatically, leading to a rise in the number of automobile workshops. The most major environmental effect of the current automobile workshops is the leakage and washing of old engine oil. Oil discharged into the environment is a common issue in the industrial world. Automobiles are a major cause to non-point source (NPS) pollution, since minor quantities of different pollutants are created by automobile operation or illegally dumped of at several sites. Automotive sector wastewater is among the primary sources of heavy metals, cyanide, organic and inorganic pollutants, oil and grease that considerably adds to the pollution load of receiving water bodies and is vital for stream contamination. Several studies relate heavy metals (such as Zn, Pb or Cu) or hydrocarbon loadings of surface water to transportation (see, for example, Davis et al. 2001; Sutherland and Tolosa 2000). Driscoll *et al.*, (1990) reported that measurable concentrations of lead, zinc, copper, and nitrite / nitrate in road runoff, with urban concentrations two to five times higher than rural concentrations. It is crucial to emphasize that heavy metals in roadway runoff are not inherently harmful, since toxicity relies on chemical form and aquatic organism availability. Furthermore, the release of toxins from these wastewater discharges to the sewer or environment has the potential to cause substantial environmental damage and health issues in human. This is due to the fact that a component of oily wastewater, such as oil, will overlay the surface of the water, preventing oxygen diffusion from air to water (Kadarwati and Herlina, 2008) and contributing to BOD (biological oxygen demand) and COD (chemical oxygen demand) in effluents water (Yasin, *et al.,* 2012). Waste water treatment methods are an essential for removing pollutants and biological substances from automotive effluents. Traditional approaches based on physicochemical operations are not practical due to their higher running costs and environmental implications, along with their requirement for technical expertise, labour management, and operational control (Massoud, M. A *et al.*, 2009).

Floating Wetland and Constructed Wetland have shown to be an effective method of dealing with wastewater (Arslan, M *et al.*, 2002). The constructed wetland is an engineering system that utilises aquatic plants and natural processes to filter pollutants from wastewater (Tayade, S. T*et al.,* 2005;

Oladejo, O. S*et al.,* 2015).The floating wetland system operates on the phytoremediation concept, in which aquatic plants remove toxins from wastewater via their roots (Lasat, 2000; Gupta, P. K*et al.*, 2015).A Floating Wetland is a hydroponic system that offers a growing medium for plants (Colares, G. S *et al.*, 2020; Afzal, M *et al.*, 2019). Constructed Wetlands are outputs of environmental technical expertise that are constructed by inheriting and executing mechanisms of natural wetlands via plant, soil, and related microorganisms for the goal of wastewater treatment (Calheiros, C. S *et al.*, 2007; Ijaz, A *et al.*, 2015). Floating wetland are readily handled, mimic a native habitat, and are a low cost approach, but constructed wetlands provide a medium with multiple layers for the purification of wastewater and a substantial physical support for plant development (Asghar, I *et al.*, 2022; Stefanakis, A. I. 2020). . The importance of plants in wastewater treatment wetlands cannot be overstated. Microorganisms, which are the most significant processors of wastewater pollutants, need a substrate from plants. Plants supply bacteria with a carbon source (Brix, H. 2003; Afzal, M *et al.*, 2019).In wetlands, plants play a significant role in removing contaminated water.Various species of plants with admirable features and the capacity to endure unfavourable and severe environments are utilized. *Typha*, *Canna*, *Iris*, *Heliconia*, and *Zantedeschia* are the most often utilized blooming plants (Sandoval, L *et al.*, 2019). Moreover, The macrophytes used were *Pennisetum purpureum*,*Eleusineindica*, *Amaranthus spinosus*and *Eichhorniacrassipes*planted in pilot scale floating and constructive wetland system (Dahake, A., &Hedaoo, M. (2018); Napaldet, J. T., &Buot Jr, I. E. (2019); Brix, H. (2003, May), Sandoval, L *et al.*, 2019).Conventional petroleum industry treatment methods, such as hydrocyclones, separators, etc., extract only dispersed oil but are incapable of removing aromatics components in dissolved water phase. Despite constructed treatment wetland's efficiency, environmentally friendly nature, and good economics, this new wastewater treatment method is still uncommon in the petroleum sector (Eke, P. E *et al.*, 2017).This study was planned to design a floating and constructive wetland system for treatment of automobile wastewater. The purpose of this study was to compare the potential of FTWs and CWs that had been vegetated with *Eichorniacrassipes* and *Eleusine indica* respectively.

2. Materials and Methods

2.1 Plants materials

Two macrophytes species, *EichorniaCrassipes* and *Eleusine indica* were collected from the *Vellayani Lake* and surrounding wetland region of Thiruvananthapuram located in Kerala. Then, plants were grown in the plot for further research studies.In this study effluent samples were taken from KSRTC automobile workshops in Thiruvananthapuram located in Kerala

2.2 Experimental setup of an adsorption column

A 16 cm internal diameter PVC (Polyvinyl chloride) pipes was used. The column was filled with Cotton, Charcoal and River sand (Figure 2)stacked alternatively one over other packing for a height of 5cm, 8 cm, and 7cm respectively (Figure 1).

Figure 1: Adsorption Column

Figure2 : Coal , Cotton , Sand

Lastly the treated water after settling in the primary tank was transferred into it. 2 litres of treated water was given in at a time. And the time to collect the 2 litre water from the adsorption column was noted to be 35 min. After the treatment of all the treated water was carefully transferred to the secondary tank. The treated water was stored here and allowed to settle until released to the wetland unit

2.3 Experimental set up of a floating wetland system

A lab scale floating wetland system (Reactors) was designed in an aquarium unit with uniform size of 2 ft ×1 ft ×1 ft(L×W×H) column made up of glass (Figure 3).

Figure 3: Aquarium unit - floating wetland system

2. 4 Experimental set up of a Constructed wetland system

A lab scale constructed wetland design (Figure 4) was made with a size of 50 cm ×32 cm ×22 cm (LWH) vertical flow system. Plastic rectangular container having inlet and exit at the top and bottom, respectively. The wetland was sandwiched with Garden soil, pebbles, gravels, and river sand from bottom to top (Figure 4). The corresponding heights of the river sand, gravel, pebbles, and garden soil layers are 3 cm, 3 cm, 5 cm, and 3 cm respectively.

Figure 4: Constructed wetland materials

Garden soil, pebbles, gravels, and river sand

Figure 5: Shower system

Figure 6: Constructed wetland unit

Flow rate was determined using the equation:

$$\text{Flow rate} = \text{volume of sample} / \text{time taken} = 100\ \text{mL}/60\ \text{s} = 1.667\text{mL/s}$$

Manually placed PVC (Polyvinyl chloride) pipes were used to disperse the wastewater flow into the constructive wetland model system (Figure 6). The shower system (Figure 5) is comprised of perforated PVC pipes and a valve that maintains a flow rate of 1,667 mL/s while flowing through a constructed wetland system. The treated effluent collecting outlet was positioned at the base of the reactor.

2.5 Operationof both Floating and Constructed wetland System

The Floating and Constructive wetland system were operated for 15 days with*Eichhornia crassipes*and *Eleusine indica*. Before transplanting, the gathered wetland plants were sized and weighed uniformly and left undisturbed for seven days to allow for establishment in reactors. The raw automobile wastewater was collected from the local automobile workshops. After establishment, the wastewater was pumped in to a primary sedimentation tank (30 liter dispenser), here the wastewater was stored in a 30 liter dispenser for about more than an hour. The particles where allowed to settle by the principle of sedimentation (Ayres, D. M *et al.*, 1994). Most of the big debris are filtered from this tank by using a filter and sedimentation by gravity. The treated water from the primary tank is then transferred to the adsorption column.. In this the majority of oil and grease is adsorbed. After primary treatment, the primary treated water was pumped to floating and constructed wetland system and monitored regularly. In this study, the treated water from both floating and constructive wetland setup were collected at different-hydraulic retention time up to 15 days.

2.6 Analytical procedures

The treated wastewater samples from the floating treatment wetlands and the constructed wetland were collected between 1 and 15 days and analysed for various important physiochemical parameters (including pH, temperature,total suspended solids (TSS), total dissolved solids (TDS), BOD, and COD in accordance with the APHA (American Public Health Association, 1998) handbook.

3. Result and Discussion

By analysing the treated automobile waste water for various physicochemical characteristics, the comparative effectiveness of floating wetlands and constructed wetlands was determined (Table 1 and 2).

Table 1: Table for analytical parameters for floating wetland

DAY	TEMPERATURE	pH	TDS	TSS	COD	BOD
Day 1	33°C	7.82	281 ppm	1.377 g	528 mg/L	205 mg/L
Day 2	29°C	7.74	302 ppm	0.728 g	713 mg/L	210 mg/L
Day 3	30°C	6.7	182 ppm	0.741 g	623 mg/L	200 mg/L
Day 4	29.7°C	°C6	311 ppm	0.879 g	581 mg/L	212 mg/L
Day 5	30°C	7.8	209 ppm	0.718 g	-	212 mg/L
Day 6	33°C	5.9	303 ppm	0.122 g	226 mg/L	187 mg/L
Day 7	33.2°C	6	305 ppm	0.171 g	210 mg/L	172 mg/L
Day 8	32.6°C	6.2	178 ppm	0.063 g	212 mg/L	-
Day 9	30.2°C	6.5	183 ppm	0.079 g	205 mg/L	179 mg/L
Day 10	29.7°C	6.9	185 ppm	0.084 g	-	171 mg/L
Day 11	29.9°C	6.72	390 ppm	0.138 g	217 mg/L	172 mg/L
Day 12	28.7°C	7.3	313 ppm	0.172 g	230 mg/L	179 mg/L
Day 13	29.1°C	5.8	349 ppm	0.281 g	267 mg/L	183 mg/L
Day 14	29°C	5.9	280 ppm	0.468 g	239 mg/L	192 mg/L
Day 15	30°C	6.2	340 ppm	0.621 g	-	171 mg/L

Table 2: Table of analytical parameters for constructed wetland

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DAY	TEMPERATURE	pH	TDS	TSS	COD	BOD
Day 1	33°C	7.82	281 ppm	1.377 g	528 mg/L	205 mg/L
Day 2	29°C	7.74	302 ppm	0.728 g	713 mg/L	210 mg/L
Day 3	30°C	6.7	182 ppm	0.741 g	623 mg/L	200 mg/L
Day 4	29.7°C	6	311 ppm	0.879 g	581 mg/L	212 mg/L
Day 5	30°C	7.8	209 ppm	0.718 g	-	212 mg/L
Day 6	33°C	5.9	303 ppm	0.122 g	226 mg/L	187 mg/L
Day 7	33.2°C	6	305 ppm	0.171 g	210 mg/L	172 mg/L
Day 8	32.6°C	6.2	178 ppm	0.063 g	212 mg/L	-
Day 9	30.2°C	6.5	183 ppm	0.079 g	205 mg/L	179 mg/L
Day 10	29.7°C	6.9	185 ppm	0.084 g	-	171 mg/L
Day 11	29.9°C	7.1	183 ppm	0.140 g	88 mg/L	56 mg/L
Day 12	28.7°C	8.2	349 ppm	0.072 g	78.3 mg/L	42 mg/L
Day 13	29.1°C	7.56	345 ppm	0.045 g	56 mg/L	26.3 mg/L
Day 14	29°C	7.9	295 ppm	0.021 g	-	-
Day 15	30°C	7.3	298 ppm	-	-	-

The evaluation of pH is an essential aspect of waste water treatment. Changes in effluent pH may affect the rate of biological reactions and the survival of certain microorganisms (Sankpal, S. T., &Naikwade, P. V. (2012). The present study investigates the pH after treatment of both floating and constructive wetland. In this study minimum pH and maximum pH are 5.8 and 7.82 (Figure 5) (Table 1) after the floating treatment wetland system. Whereas, minimum pH and maximum pH are 5.9 and 8.2 (Figure 7) (Table 2) after the constructive wetland treatment. This acidic condition is because of the heavy metal content in water and after treatment pH changed to neutral level (Zhang, Y *et al.*, 2018). The pH remained neutral for constructed wetland.

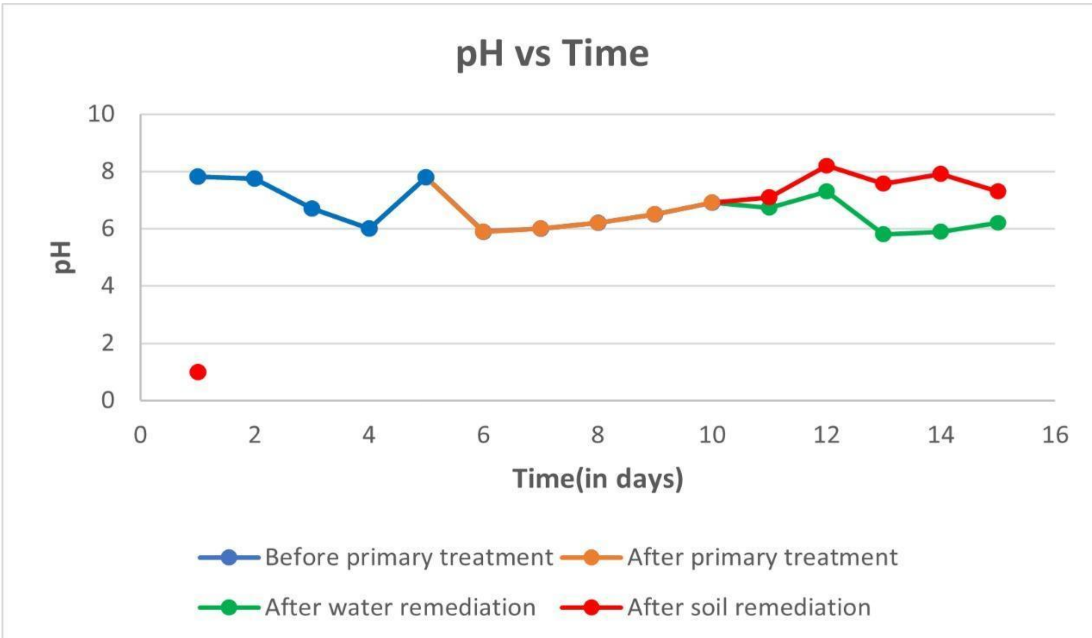

Figure 7: Variation in pH value Before after primary treatment , Floating and Constructed wetland treatment

Temperature influences the physicochemical properties of water and waste water (Rabah, F. 2018). The rate of different biochemical reactions depends on the temperature (Alisawi, H. A. O. (2020). Atmospheric temperature as well as seasonal changes influence the removal of contaminants in floating and constructed wetland system (Van de Moortel*et al.*, 2010, Werker, A. G *et al.*, 2002). In the floating wetland, minimum temperature was found to be 29°C and maximum temperature was 33°C.This was due to changes in climatic conditions (Table 1) (Figure 6). While in the constructive wetland, minimum temperature was found to be 28.7°C and maximum temperature was 33.2°C (Table 2) (Figure 8).

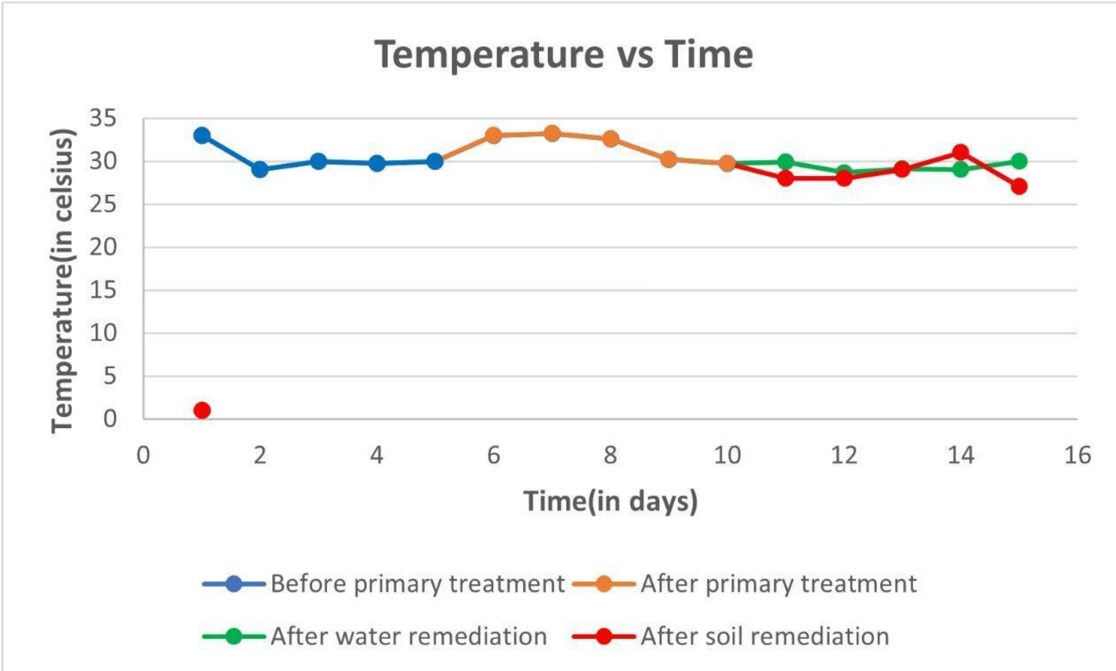

Figure 8: The temperature variation during the primary treatment, floating and constructive wetland treatment

Total suspended solids (TSS) play a crucial role in the floating and constructive wetland treatment of waste water (Tanner, C. C., & Headley, T. R. (2011), Sehar, S *et al.*, (2015). During the floating wetland treatment, the minimal TSS was found 0.063g and maximum TSS was found 1.377. In case of the TSS the adsorption column study shows minimum value. In the case of treatment using *Eichhornia crassipes* plant (water hyacinth) the TSS study shows an increasing value due to the wilting of plant in lab scale. TSS value is reduced from 1.377g to 0.021 g during constructed wetland study (Figure 9) (Table 2).This is mainly due to primary treatment (settling and sedimentation) of suspended solids and physical adsorption while passing through adsorption column which contain coal, cotton and river sand.

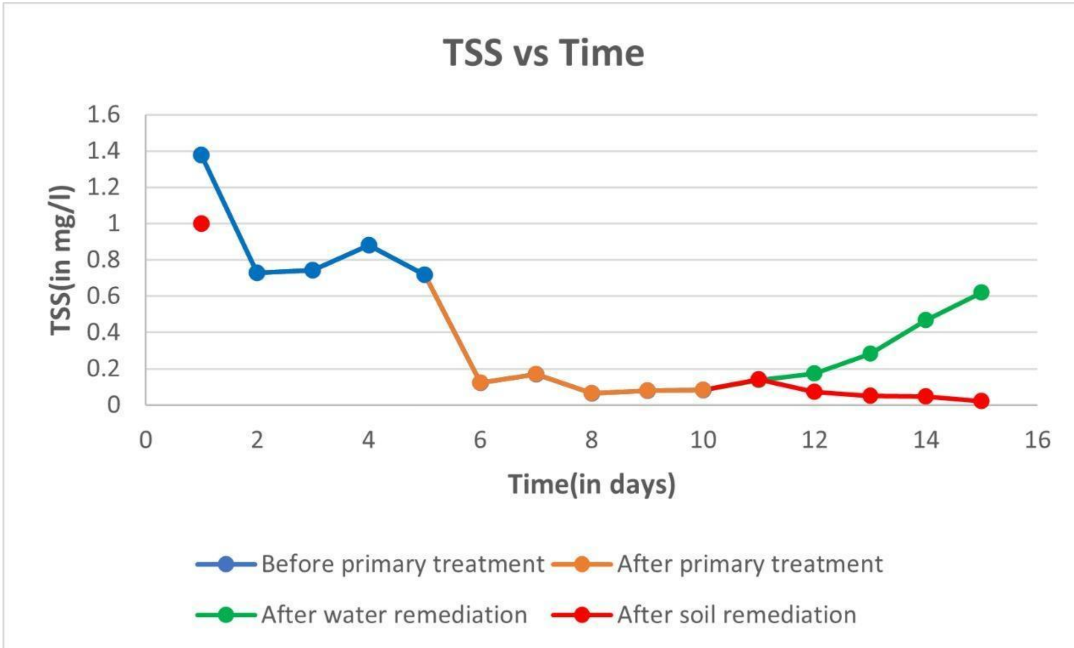

Figure 9: The TSS value during the primary treatment, floating and constructive wetland treatment.

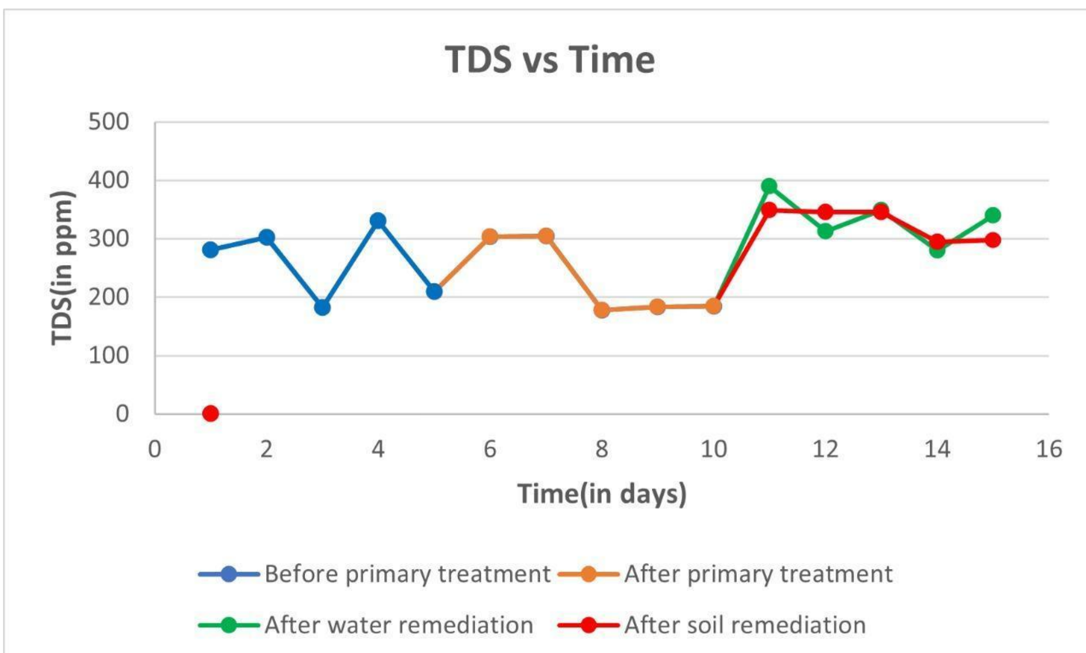

Figure 10: The range of TDS values during the primary treatment, floating and constructive wetland treatment.

Total dissolved solid (TDS) is a wastewater quality measurement used to evaluate the effectiveness of floating and constructed wetlands for the removal of organic matter and to quantify the pollution level in many vehicle wastewater effluents. There is a significant concentration of dissolved solids in waste water. During the floating wetland pilot study, the minimum value of TDS obtained was 178 ppm and the maximum value was 390 ppm (Figure 10). High level of TDS was aesthetically unsatisfactory and may also produce distress in human and livestocks (Sugasini, A., & Rajagopal, K. (2015). Whereas TDS value is reduced in constructed wetland study (Figure 10). The constructive wetland system exhibited a higher TDS removal than the floating wetland system.The constructive wetland system removed more total dissolved solids (TDS) than the floating wetland system. When wastewater with a high concentration of total dissolved solids (TDS) is released into surface or groundwater, these dissolved solids may be a significant source of pollution (Udom, I. J *et al.*, 2018).

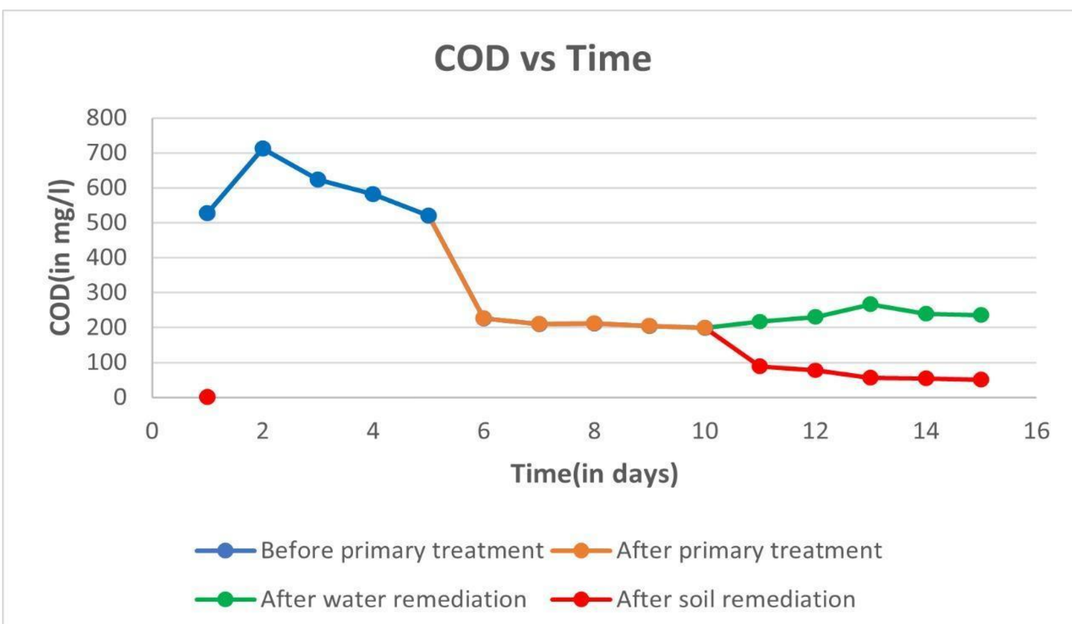

Figure 11: The COD values variation during the primary treatment, floating and constructive wetland treatment

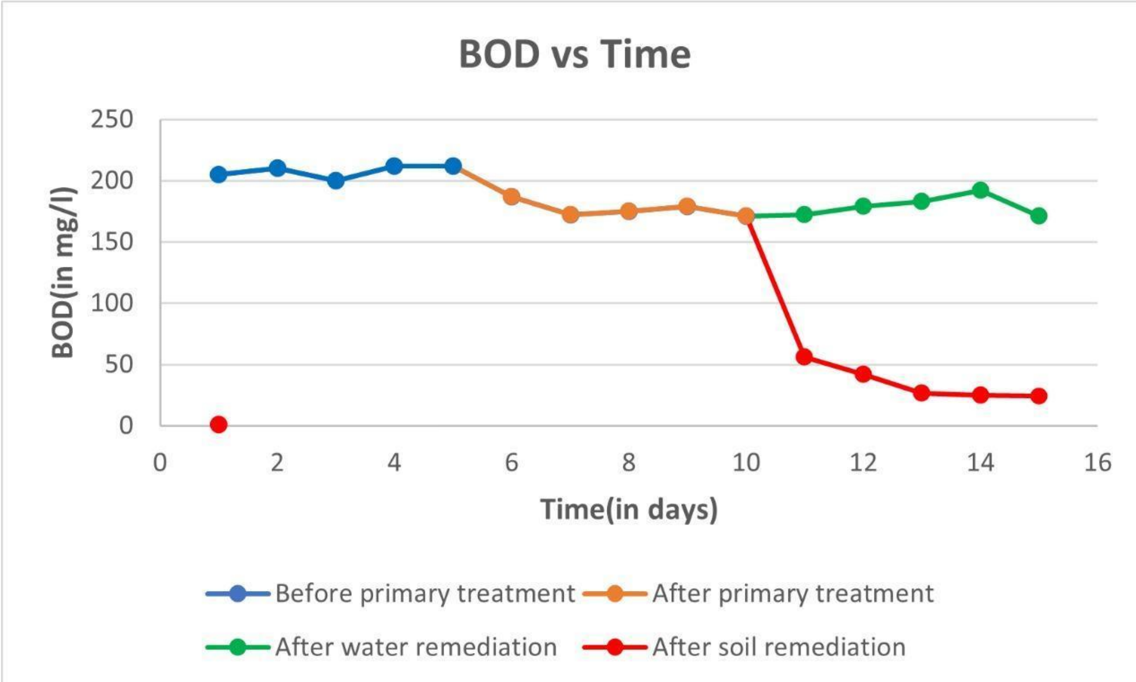

Figure 12: The BOD values variation during the primary treatment, floating and constructive wetland treatment.

BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) are essential markers for identifying the quality of effluent. The Chemical Oxygen Demand (COD) test is the most commonly used technique for assessing organic matter and the fastest test for calculating the total oxygen demand by organic matter in a sample (Jhamb, S *et al.*, 2020). During the floating wetland pilot study, the minimum COD value obtained was 205 mg/l and the maximum value was 713 mg/l (Figure 11). The minimum value was obtained during the adsorption column study. But COD value was increased during treatment with aquatic plant due to its wilting. A high concentration of organic molecules that are resistant to bacterial breakdown may account for a rise in COD levels (Jain, M. *et al.*, 2020). Calculation of Biological Oxygen Demand (BOD) is one of the major factors used in assessing the effect of waste water on receiving water bodies. Elevation in BOD, which is a reflection of microbial oxygen demand, results in the Dissolved Oxygen (DO) depletion, which may lead to hypoxia and have negative impacts on the aquatic environment. The minimum and maximum value of BOD obtained was 171 mg/l and 212 mg/l in floating wetland (Figure 12). While the minimum and maximum value of BOD obtained was 212 mg/L and 26.3 mg/L in constructed wetland (Figure 12).The constructed wetland systems efficiently minimize the biochemical oxygen demand (BOD).

4. Conclusion

This study evaluates the efficacy of both floating and constructed wetland for the treatment of automobile waste water. The application of constructed wetland treatment resulted in a large amount of pollutant removal. These pre-treated water might be reused for agricultural, aquifer replenishment, industrial cooling, aquaculture, and household uses, among others. A combination of high-tech methods for treating wastewater is deemed improper since it is often economically unfeasible. As a result, there is a pressing need to create acceptable, economical, and efficient wastewater treatment and reuse solutions instead of costly and time-consuming existing treatment technologies. Recycling wastewater is a commonly accessible approach for addressing the water supply constraint. In the approaching decades, wastewater treatment and recycling systems will be essential for providing adequate freshwater supplies. Wetland technology was deemed to have the most potential in terms of pollutant removal, as well as low maintenance costs and energy requirements, when compared to other methods currently used in urban wastewater reuse for irrigation. The operating and maintenance expenses of constructed wetland treatment systems are much lower than those of traditional treatment systems. This process is prevalent in natural wetland ecosystems, but similar activities are conducted under more controlled conditions in constructed wetland ecosystems. All forms of constructed wetland are very successful at removing organics and suspended particles, although nitrogen removal is less efficient and might be enhanced by combining several types of constructed wetland. To this purpose, environmentally friendly remediation strategies are recommended, especially in nations with limited economic restrictions. The renewable energy method of gasification turns carbon-based waste to heat and electricity. There are several types of gasification, according on how the process operates. It is an effective method for converting hazardous waste into heat and electricity. Biomass gasification is the thermochemical conversion of organic (waste) feedstock in a high-temperature environment, which enables biomass to be converted not only to syngas for energy production but also to chemicals, including ethylene, methane, fatty acids, adhesives, plasticizer, surfactants, and detergents.

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