ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Original Research Article

Sewerage Water Treatment Using Phytoremediation

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Abstract: Surface water is contaminated by various toxic elements through anthropogenic activities and natural sources between residential and premises. Studies have shown that aquatic plants can improve surface water quality by purifying polluted surface water. Many studies have been introduced to treat sewerage water in conventional design. Sewerage Treatment Plant (STP) development has become a key business and has cost the public and industries. Thus, sewerage treatment increased productive living costs after the global water and electricity tariffs. In this study, sewerage water at urban, rural, remote, or even islands could use some aquatic plant as an alternative sewerage water treatment. The study aims to identify the effectiveness level of certain marine species suitable for sewerage water treatment. Some aquatic plants were used in this study to determine the level of chemical absorption from wastewater. The testing plot was located in a small basin with constant, and water flow from the sewerage holding tank was controlled. This study used sewerage water from Puchong's Sewerage Treatment Plant as a polluted source. The water quality at each basin was monitored and recorded daily at a constant water quality reading. The study found that certain aquatic species could absorb some chemical characteristics during the phytoremediation process, as seen by many previous studies. The treatment of sewerage sources for this study had deteriorated by over 20% from the sewerage characteristics using different species. This identified that alternative wastewater treatment using some species could treat selected sewerage water characteristics within a period. Further studies could be done to improve the treatment timeframe either on a different scale or in an integrated treatment mode to treat other wastewater characteristics.

Keywords: phytoremediation; water; treatment; aquatic; sewerage

Received: 15th February 2021

Received in Revised Form: 13th November 2021

Available Online: 17th January 2022

Published: 22nd December 2022

Citation: Omar, N.A., Wahap, M.H., Johar, Z, Sewerage water treatment using phytoremediation. *Adv Agri Food Res J* 2022; 3(2): a0000262. https://doi.org/10.36877/aafrj.a0000262

1. Introduction

Today, socioeconomic had faced the challenge of balancing environmental quality with market capitalisation (USEPA, 2017). Pollutants associated with socioeconomic activities, such as industrial and agricultural runoffs, have become concerned about environmental health (Fidelis *et al.*, 2020). Today, it has been a challenge to have efficient and effective treatment (Aluwi *et al.*, 2013). In Malaysia, about 99% of water source comes from surface water (Zurahanim *et al.*, 2020). Rapid urban and suburban industry growth has increased population intensity in a particular city in Malaysia, resulting in sewerage volume affecting surface water pollution in rivers, lakes, ponds, or natural wetlands. Malaysia's population has been given impacted by water demand. New residential had been planned to be developed for domestic orders. Thus, water consumption led to the continuous production of sewerage effluent discharged from new development area. The commercial area allows sewage effluent, which becomes a significant contributor to water pollution, followed by industries (Janssen *et al.*, 2015). Between 300 to 700 tons per day of sewage have been reported by the Department of Environment as part of the domestic discharges, accounting for a high proportion of the organic and inorganic (MEQR, 2017–2020).

This conventional sewerage treatment will not cope with varying nutrient loads at various volumes of sewerage discharged. Thus, extended treatment treating sewerage at a low cost of operation will save the environment and secure the drinking water treatment plant (Sarah & John, 2018). This nature-based solution has become popular in many countries (Haseeb, 2021; Meagher, 2003). However, many researchers have confirmed that certain aquatic plants could treat sewerage effluent through the phytoremediation method. Some phytoremediation plants have been tested, such as *eichhornia crassipes* (water hycinth), *genus lemna* (duckweeds), and others, for instance, have given different results of nutrient absorption (Janssen *et al.*, 2015).

Phytoremediation, which relies on plants to take up and transform the contaminant of interest, is another alternative treatment method developed (Ramu, 2019). The commercialisation of phytoremediation treatment could not be used for all types of effluent; therefore, it is not widely used, mainly due to its low treatment efficiency (Raza *et al.*, 2020). Certain aquatic plants can transform and extract, even removing unwanted chemical properties of contaminants (Weyens *et al.*, 2009). For example, plants such as *Eichhornia crassipes* could reduce wastewaters' specific parameter values such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and phosphate (Aremu *et al.*, 2012). Standard phytoremediation practices are at artificial ponds, urban rivers, constructed wetland, lakes, or vegetative filters, which had managed some landfill sites.

Phytoremediation offers the advantage of pollution extraction without disturbing the land area. Heavy metal pollution from effluents is a significant surface water problem and has proven its impact on the community environment and its ecosystem (Salt *et al.*, 1995). However, over accumulation of heavy metals contamination became toxic to most plants, decreasing soil fertility and affecting the microbial activity and soil yield losses (Zain *et al.*, 2013). Thus, research and development of phytoremediation strategies for contaminated water, including sewerage, is necessary.

This study's objective is to determine the performance of particular aquatic species by comparing the level of treatment on sewerage effluents from the sewerage treatment plant using the phytoremediation concept.

2. Materials and Methods

This study had four aspects of materials preparation and experimental arrangement. Those aspects consist of: (i) sources of sewerage; (ii) aquatic plants; (iii) experimental arrangement; and (iv) sampling for data collection analysis. The study illustrated ad in Figure 1.

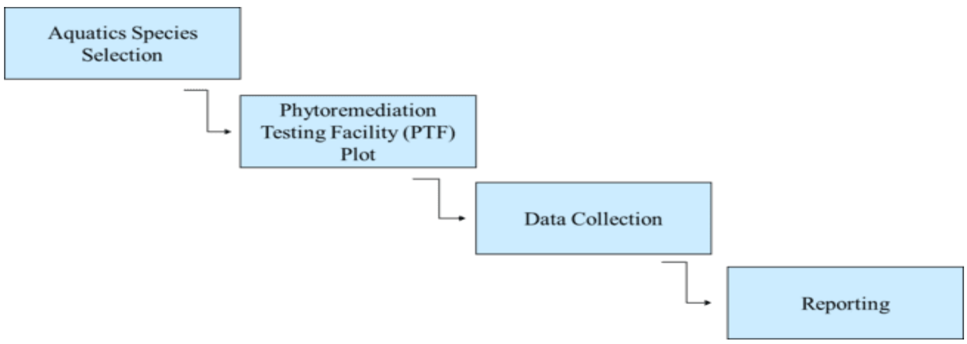

Figure 1. Phytoremediation Testing Facility (PTF) Plot where sewerage effluent is being tested.

2.1. Sources of Sewerage

The sewerage sources were collected in the nearby one of the Sewerage Treatment plants (STP) from Puchong, Selangor. Sewerage is pumped into a portable tank and transported from STP to the Phytoremediation Testing Facility (PTF) Plot as in Figure 2. As the distance took less than 30 minutes, all sewerage from portable tank was pumped out into each aquatic plant basin upon arrival. In this test, the effluent from STP was sampled every seven days to control the same effluent characteristics (Pillai & Kottekottil, 2016).

Figure 2. Phytoremediation Experimental Plot (PEP) where sewerage effluent is being tested.

2.2. Aquatic Plants

This study used eight aquatic plants, as shown in Figure 3. The plants are: *Scirpus grossus*; *Ipomoea aquatic; Pennisetum purpureum; Cyperus alternifolus; Typha angustifolia; Eleocharis dulcis; Eichornia crassipes;* and *Chrysopogon zizaniodes*.

Figure 3. Selected species of aquatic plants used for Phytoremediation Experimental Plot (PEP).

2.3. Experimental Arrangement

Each aquatic plant had been located on each basin with minimal effluent flows. Water pumps fed each bay to have equal circulation flows. Extra circulation pumps had been installed on each basin to let effluents reach into the area of the plant's roots**.** In this test, the effluent from STP was sampled every seven days to control the same effluent characteristics as in Figure 4 (Deborah, 1996). Inside the study plot, as shown in Figure 4, plants were put into three small HDPE basin for each species with some connection. About 25 small HDPE basins are used for eight species, including one control basin basin, whereas only sewerage water had been put without plants.

Figure 4. Plant on each basin ready during the testing period.

2.4. Sampling for Data Collection and Analysis

Daily data was taken and monitored to analyze the effluent measurement changes during the testing period. Samples were collected from each plant after 3–5 days and sent for laboratory analysed, as shown in Figure 5.

As in Figure 5, samples were collected before, during, and after the testing of each basin. All models were sent to the Water Quality Laboratory of NAHRIM to analyse parameters of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Organic Compound (TOC), Ammoniacal Nitrogen, Total Suspended Solid (TSS), Total Dissolved Solid (TDS), Nitrate, Phosphate, and colours. All laboratory standard operating procedures followed American Public Health Association (APHA) Method 9221 (WMO, 1994). Data were sorted and analysed using Microsoft Excel, converting all data to be in the trend of timeline basis to evaluate each parameter's performance and each aquatic species.

Figure 5. Samples were taken or further analysed.

3. Results and Discussions

After nearly 30 days of testing, the sewerage water had been treated by various species. From the laboratory data, most of the sewerage had been treated within 14 days. All parameters had met the target of the objectives, whereas all species had treated the sewerage water above 20%, as in Table 1. The performance of the species is illustrated in Figure 4.

Table 1. Each plant testing performance through the phytoremediation process.

Plant Species	% Treatment Reduction
Scirpus grossus	67%
Ipomoea aquatic	56%
Pennisetum purpureum	40%
Cyperus alternifolus	33%
Typha angustifolia	29%
Eleocharis dulcis	21%
Eichornia crassipes	20%
Chrysopogon zizaniodes	16%

From the studies, parameters that were measured are Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Organic Compound, Ammoniacal Nitrogen (NH_3-N), Total Suspended Solid, Total Dissolved Solids, Nitrate (NO_3), Phosphate and colour. Certain parameters are resulting moderate performance, whereas the sewerage nutrient loading is less than before treatment. These show that all tested aquatic species could use the phytoremediation concept for sewerage water treatment. All results were summarised for all species performance compared to sewerage water results, as shown in Table 2.

Table 2. The overall average result after the laboratory testing.

Species/Parameters	BOD5	COD	TSS	TDS	TOC	PO4	NH_3-N	NO3	Colour
Eichornia crassipes	55.80	115.00	13.00	203.00	23.41	5.42	23.31	[ND]	76.00
Eleocharis dulcis	67.10	106.00	21.00	191.00	23.91	7.33	25.65	[ND]	118.00
Pennisetum purpureum	49.90	111.00	13.00	195.00	27.85	5.79	25.79	[ND]	199.00
Cyperus alternifolus	49.80	99.00	14.00	195.00	23.08	6.27	21.06	[ND]	147.00
Phragmites karka	47.90	107.00	20.00	201.00	23.99	7.42	29.88	[ND]	111.00
Ipomoea aquatica	60.60	96.00	16.00	205.00	22.74	4.65	20.53	[ND]	105.00
Typha angustifolia	45.90	102.00	16.00	191.00	23.72	5.21	24.43	[ND]	164.00
Chrysopogon zizaniodes	45.20	84.00	21.00	145.00	23.99	6.84	26.48	[ND]	94.00
Scirpus grossus	47.00	120.00	21.00	187.00	20.53	5.81	22.76	[ND]	124.00
Saccharum spontaneum	48.80	94.00	21.00	211.00	23.40	6.32	26.40	[ND]	87.00
Lepirona Articulate	47.60	91.00	22.00	210.00	14.93	6.63	26.73	[ND]	80.00
Sewerage Water	**47.89**	**107.33**	**19**	**200**	**22.56**	**6.16**	**25.92**	**[ND]**	**86**

Among all the species of *Scirpus grossus; Ipomoea aquatic; Pennisetum purpureum; Cyperus alternifolus; Typha angustifolia; Eleocharis dulcis; Eichornia crassipes;* and *Chrysopogon zizaniodes*, only specific parameters had given a significant performance whereas the sewerage water had become more treated. Total phosphate gave a different result for each plant. As in Figure 6, significant changes reflected a high level of the phytoremediation process.

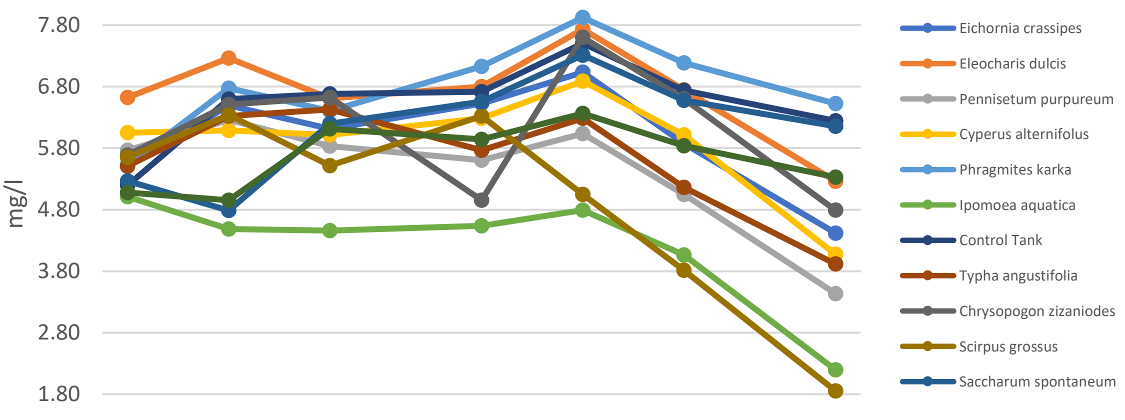

Figure 6. Performance trend for Phosphate of all species of the testing plants.

As in Figure 6, the most significant performance species are *Scirpus grossus; Ipomoea aquatic; Pennisetum purpureum; and Typha angustifolia*. The performance could be tremendously seen after a few days, as in Figure 7. The species performance formulation of *Scirpus grossus; Ipomoea aquatic; Pennisetum purpureum; and Typha angustifolia* respectively are: (i) y = -0.1174x2 + 0.6197x + 4.0905, R^2 = 0.759; (ii) y = -0.2319x2 + 1.251x + 4.5686, R^2 = 0.9491; (iii) y = -0.1431x2 + 0.8166x + 5.0224, R^2 = 0.8655 and (iv) y = -0.1674x2 + 1.0802x + 4.6538, R^2 = 0.8935. From the formulation, the R^2 range was between 0.7 and 0.9, while the constant number was between 4.0 and 5.0. This shows the characteristics of treatment using phytoremediation over a certain period and could be as performance to compare with different species. The polynomial trendline of all species also shows improved water quality to be better before treatment—the same findings for certain parameters and species from Catur (2017).

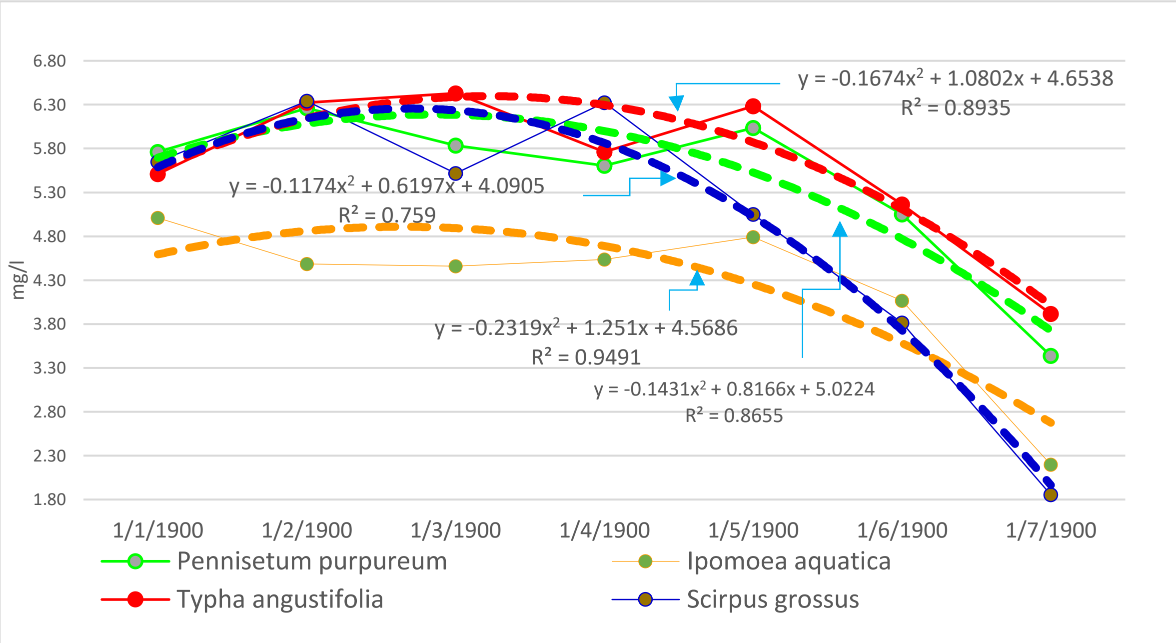

Figure 7. Most Performed Species under Parameter of Phosphate.

4. Conclusions

Although particular species were found to meet objectives, further studies could be done in the testing time for species: *Scirpus grossus; Ipomoea aquatic; Pennisetum purpureum;* and *Typha angustifolia*. This result was compared with previous findings and found a similar opinion that aquatic plants had the potential to treat wastewater (Abid *et al.*, 2020). Other potential studies are to upgrade the method of testing by lowering the incoming flow rate; to expand the basin volume in vertical/horizontal installation; to be tested with different sources of contaminated water such as canteen, restaurant, domestic grey/black water; and to be tested with other common aquatic plants such as floatables types, submerged types or different types. This study met the objectives that phytoremediation could treat sewerage water and possibly be a nature-based solution.

Acknowledgments: The author would like to thank Dato' Ir. Dr. Hj. Md. Nasir bin Md. Noh, Director General of NAHRIM, Ir. Mohd Zaki bin Mat Amin, Deputy Director General of NAHRIM, Ts. Hj. Zubaidi bin Johar, Director of Research Center for Water Quality and Environment. Special appreciation to the research team of 2014 and research team of 2020 led by Research Officer Mohammad Huzaifah Wahap and Research Assistant Shahrani Mamad for onsite data collection, data analysing, and a series of technical research reports.

Conflicts of Interest: The authors declare no conflict of interest.

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