EP23

Phytoremediation of Nutrient Contaminants from Golf Courses Surface Water

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Keywords: Phytoremediation; Nutrients; Golf courses.

Introduction. Currently, as there is a growing popularity in playing golf, a lot of golf courses have been built. To set up and maintain the turf grass of golf courses, fertilizers are applied intensively to stimulate grass growth as the tremendous small vehicle traffic and foot load are related to its daily operation [1]. However, these activities become a threat to the surrounding ecosystem when the residual of fertilizers are transported to both the adjacent water body and soil surface. This potentially represents soil leaching [2] and leads to an eutrophication phenomena [3,4].

Phytoremediation is one of recognized phytotechnologies in order to reduce or remove the load of contaminants of eutrophic water [1,4,5], where hyper-nutrients-substances (mainly nitrogen and phosphorous components) are presented. While the practice of nutrients is mainly focused on soil leaching perceptive, Evans and Furlong [6] suggested that phytoremediation approaches are the ideal solution to trap these substances from entering the groundwater. Moreover, the root systems (rhizosphere) are able to attach and directly uptake the contaminants into their tissues. The root systems also physically stabilize the soil from erosion, protect groundwater from leaching, and prevent off-site movements of the contaminants.

Both of the sampling sites of this study did not provide any treatment for storm runoff and irrigation water. The surface water is managed using retention ponds for temporary storage before being directly released to the water body nearby. Reflecting upon this fact, Kohler *et al*. [1] have also mentioned that the surface water discharges into monsoon drains after temporary storage contains high concentration of nutrients.

Therefore, this present study is conducted to remove the nutrients from the surface water of two golf courses by using the phytoremediation system. *Caladium sp.* and spinach (*Spinacia oleracea*) were used in our study to demonstrate that local plants also may have higher nutrients removal or uptake than others macrophytes. The results of this study may be used for new treatment of golf course surface water since this emerging technology is becoming significant towards green technology for national development.

Materials and Methodology.

Sampling Site and Collection. The two golf courses sites were the Royal Malaysian Air Force (RAMF) Recreation Club and the Sime Darby (SD) Golf Academy Course which are located in Shah Alam, Malaysia (Fig. 1). Water samples were collected, approximately 1m from the shoreline ponds of both the golf courses and stored at 4°C before analyzed immediately within a day.

Description of Plants. *Caladium sp.* and spinach (*Spinacia oleracea*) were collected from the Section 8 Lake in Shah Alam. Each part of the plants was cleaned thoroughly with distilled water [7], softly trashing the soft tissues, before placing them in separated containers.

Experimental Design. The treatment was conducted in the Hydrology Laboratory in Universiti Teknologi MARA (UiTM) in Shah Alam. The phytoremediation systems were designed based on stagnant condition. The plants were cultured separately in a system (0.66 m x 0.44 m x 0.35 m) filled with 24 L of surface water from both the golf courses and in another system as containment without any plants. As for the experiment, surface runoff was further filtered by using a cotton sieve to trap the major suspended solids. Volume losses in the treatment due to water sampling and/or evaporation were countered by adding distilled water [5]. The experiment was conducted over a 12 day period where the surface water of each system was sampled on days 0, 3, 5, 7, 10 and 12 in the morning.

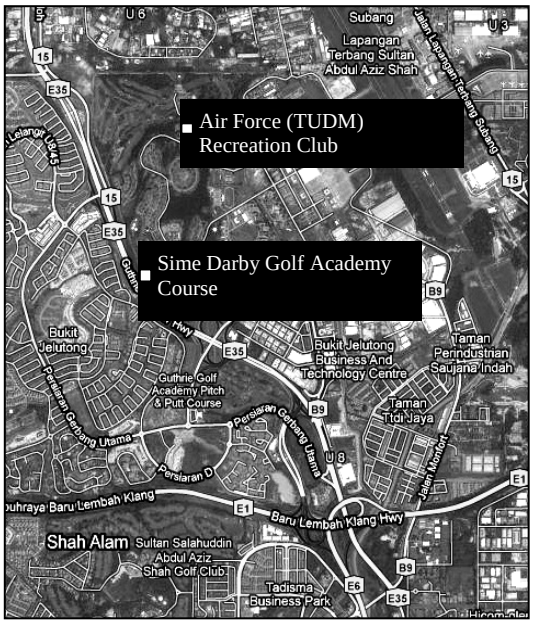


Fig. 1: Arial photo of the Royal Malaysian Air Force Recreation Club (RMAF) and Sime Darby Golf Academy Course (SD) indicating water sampling sites [8].

Water Samples Analysis.
Analysis of pH and Turbidity. The pH of the water was measured with a pH meter and the turbidity with a turbidity meter using the procedures described by the Hach Company [9].

Analysis of Nutrients. The TN, PO_4^{3-}, K and SO_4^{2-} were measured and analysed for the water samples within 12 days of treatment for both the phytoremediation and control tanks. Water samples were determined by using a Spectrophotometer DR5000 according to the Persulfate

Digestion Method (10071); PhosVer 3 with the Acid Persulfate Digestion Method (8190); Tetraphenylborate Method (8049); and Sulfaver 4 Method (8031) [9].

Results and Discussion.

Effect on pH and Turbidity in Golf Course Surface Water. The pH level was kept within an alkaline range (highest 7.47) in both the systems (Fig. 2). All the plant treatments exhibited a pH value reduction while the containment groups increased due to the utilization of the carbonate compounds during the algal photosynthesis (Chang *et al*., 2006). Although the pH values were not consistent each day, it still followed World Health Organization (WHO) Drinking Water Standard [10] which indicated a pH of 6.5 to 8.5.

The turbidity of the phytoremediation systems in the RMAF and SD reduced to the final levels of 0.76 NTU and 1.32 NTU, respectively compared to control systems which reduced to the level of 3.29 NTU. Somehow, turbidity in the phytoremediation system was significantly declined where *Spinacia oleracea* system able to reduce more turbidity level higher than other two systems at all sampling times. These results highlighted that the roots of the plants were proficient to trap particulate matters during the 12 days of treatment. Thus, results of turbidity did not exceed desirable level of turbidity (less than 5 NTU) according to WHO Drinking Water Standard [10].

Effect on Nutrients in Golf Course Surface Water.

Total Nitrogen (TN). After 12 days of treatment, *Caladium sp.* and *Spinacia oleracea* have been proven as one of the hyper-accumulators of Total Nitrogen (TN) in this experiment. *Caladium sp.* effectively removed 93% and 77% of TN reduction in the RMAF and SD systems, respectively. Meanwhile *Spinacia oleracea* removed 86% and 81% of TN reduction in the RMAF and SD systems, respectively. These results are similar with those in the experiment of Chang *et al*. [4] and Xian *et al*. [5]. Chang *et al*. [4] also discussed those nitrogen components as TN reduction is due to the nitrification or de-nitrification process at the roots systems, and it provides a condition for microbes to enhance this process in the system. Nitrogen uptakes by plants are important for biomass production and protein synthesis.

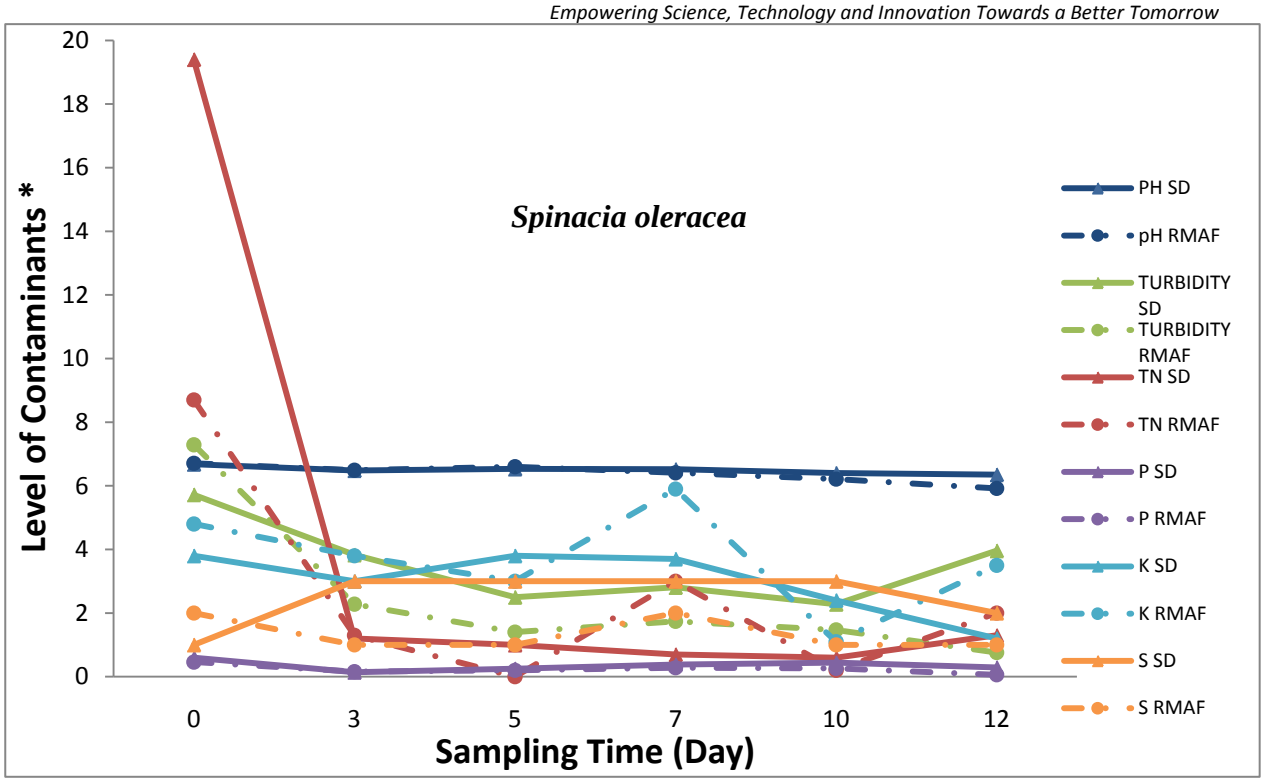
Phosphate (PO_4^{3-}). The 12-day period of reduction of PO_4^{3-} for phytoremediation and control system are given in Fig. 2. In this present study, *Caladium sp.* removed 52% and 87% of PO_4^{3-} in the RMAF and SD surface water of phytoremediation systems, respectively. However, the *Spinacia oleracea* groups exhibited a lower reduction of PO_4^{3-} in the RMAF of phytoremediation system but an increment of 60% in the SD of phytoremediation system. Among the three plants, *Caladium sp.* showed the potential to reduce PO_4^{3-} from surface water. Xian *et al*. [5] reported the reduction of phosphorous components due to uptake of soluble P in the plant tissues, filtration of particulate matter by roots and the settling process.

Potassium (K). The movement of K for plants and the control groups are given in Fig. 2. At the end of the study, *Caladium sp.* showed a reduction of 68% and 27% of K for the SD and RMAF water sampling after 12 days, respectively. Somehow, in *Spinacia oleracea* groups, the levels of K increased to 90% and 12% for both the SD and the RMAF surface water at 12 days sampling, respectively. From the other studies as well as Kohler *et al*. [1], it was noted that the K

concentration rose as natural wetland communities tended to export K. The final concentration of K in all systems except for *Spinacia oleracea* groups of SD yet did not exceed 8.00mg/L. This value for K concentration is guidelines for the Canadian Province Treated Tap Water [11].

Sulfate (SO_4^{2-}). Although the results (Fig. 2) showed significant differences within a day, all the systems were well under the World Health Organisation (WHO) Drinking Water Standard [10] which was below 500mg/l. The fluctuating values of SO_4^{2-} in all treatment systems may be due to lower initial concentrations of both surface water that not affect to plant's uptake.

Caladium sp.



(a)
(b)
(c)

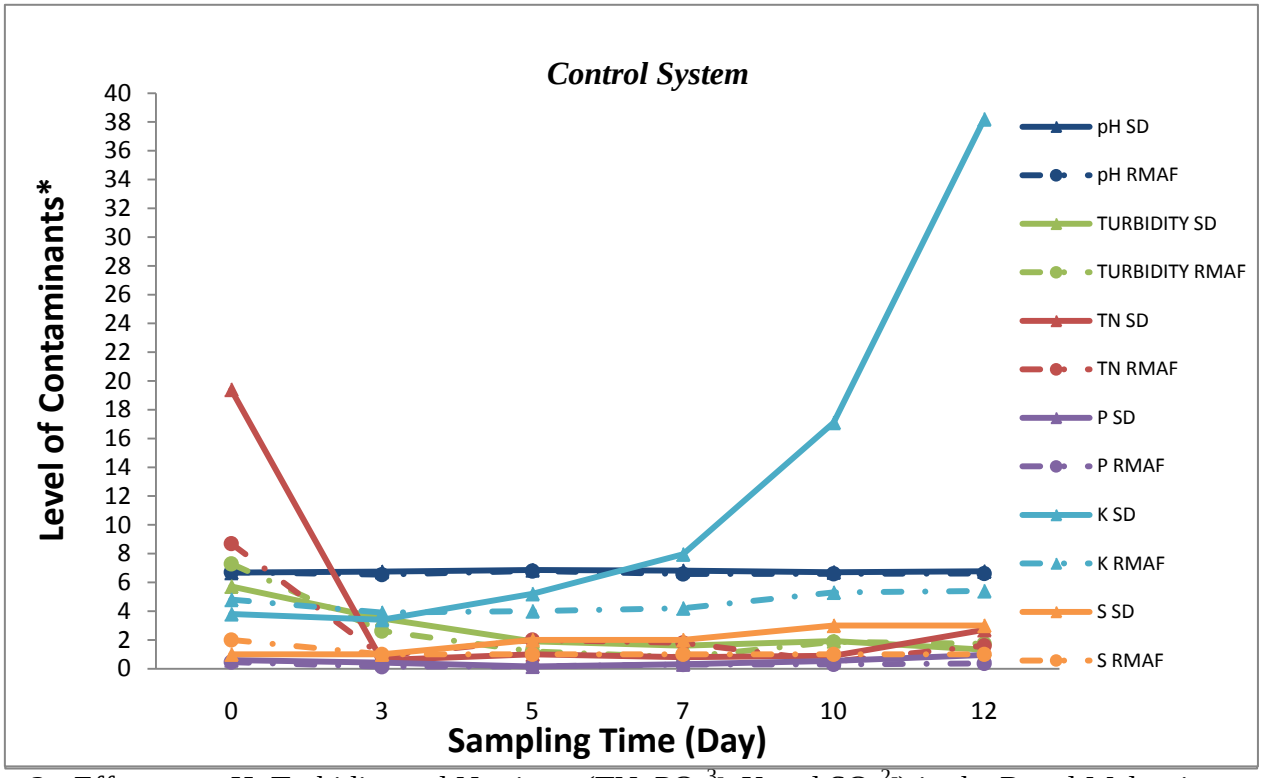


Fig. 2 : Effects on pH, Turbidity and Nutrients (TN, PO_4^{3-}, K and SO_4^{2-}) in the Royal Malaysian Air Force Recreation Club (RMAF) and Sime Darby Golf Academy Course (SD) Surface Water

with treatment time as affected by (a) *Caladium sp.*, (b) *Spinacia oleracea* and (c) without any plant (control)
*Unit for Turbidity=NTU and Nutrients=mg/L

Conclusion. Based on these results, it can be concluded that macrophytes which are *Caladium sp.* and *Spinacia oleracea* are able to uptake chemical nutrients by using the phytoremediation system. The experimental results show that different plant species have different variation abilities for nutrient uptake. Further work in this study needs to go on with the analysis of the plant tissues for nutrient uptake and for the relationship between plant survival and growth in the phytoremediation system.
The establishment of phytoremediation system in golf course management within surface water for water reuse is highly recommended. This method becomes effective because of its financial and aesthetic aspects. It is hoped that the reuse of surface water in golf clubs will mitigate the scarcity issue and at the same time the water can be reused for the golf clubs' own facilities which could be for turf grass irrigation, gardening or building use (e.g. toilet flushing).

Acknoledgements. This research work was supported by a grant from Research Management Institute (RMI), Universiti Teknologi Mara (UiTM). We also thank to our UiTM for laboratory facilities and both from Royal Malaysian Air Force (RMAF) Recreation Club and Sime Darby (SD) Golf Academy Course for their permission to collect surface water samples.

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