Performance of Phytogreen Zone for BOD_5 and SS Removal for Refurbishment Conventional Oxidation Pond in an Integrated Phytogreen System

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***Abstract*—**In this study, the effectiveness of an integrated aquatic plants in phytogreen zone was studied and statistical analysis for the promotional integrated phytogreen system approached was discussed. It was found that's the effectiveness of using aquatic plant such as *Typha angustifolia* sp., *Lepironia articulata* sp., *Limnocharis flava* sp., *Monochoria vaginalis* sp., *Pistia stratiotes* sp., and *Eichhornia crassipes* sp., in the conventional oxidation pond process in order to comply the standard A according to Malaysia Environmental Quality Act 1974 (Act 127); Environmental Quality (Sewage) Regulation 2009 for effluent discharge into inland water near the residential area was successfully shown. It was concluded that the integrated phtogreen system developed in this study has great potential for refurbishment wastewater in conventional oxidation pond.

***Keywords*—**Phytoremediation, integrated phytogreen system, sewage treatment plant, oxidation pond, aquatic plants.

I. Introduction

THROUGH the years, the artificially constructed wetlands for wastewater treatment have been increasing worldwide. One of the reasons is the recognition of constructing wetlands as eco-technology, thus giving benefit to small towns or industries that cannot afford expensive conventional treatment systems [1]-[3]. The high cost of conventional wastewater treatment process has restrained the economy and forced the engineers to search for creative, cost-effective and eco-friendly solutions.

Increasing growth in the human population, uncontrolled exploitation of natural resources and urbanization has resulted in the generation of huge amounts of liquid and solid waste. The generation of liquid waste is predominantly due to domestic sewage. Economical and effective treatment of sewage is one of the most challenging problems faced worldwide [4]-[6]. The most common method of sewage treatment in

India is using the oxidation pond or activated sludge process. These processes are ineffective, expensive and require complex operations and maintenance [7], [8]. In India hardly 10% of the sewage generated is handled effectively, while the rest of the sewage finds its way into the ecosystem and causing large-scale pollution to rivers and ground waters [3], [9], [10].

From the recent evidence, it is proved that wetlands can remove contaminated nutrients and suspended solids from the wastewater [1], [5], [11]. The selection of this method for the wastewater treatment is as it treats the wastewater at the lowest possible cost. The artificial wetland system is known as one of the eco-technology that can be used as an alternative to septic tank which is normally used in small and isolated communities [12]. Although only a few studies have been done on wetlands in Tanzania, some encouraging results showed the possibility of using this eco-technology method for the wastewater treatment [12]. Currently thousands of constructed wetlands worldwide have received and treated a variety of municipal, industrial and urban runoff wastewaters [13]–[16].

Water hyacinth *(Eichhornia crassipes*, family *Pontederiaceae*) is one of the most productive plants on the earth [1], [10], [17]. Thus, consider it as the world's worst aquatic plant [18], [19]. Known as "Blue Devil", this plant is a high water consumer and has incredibly dense mats of free-floating vegetation blocks [17], [20]. However, there are studies of water hyacinth as a very promising plant with tremendous applications in wastewater treatment was done [5], [21]-[23]. In the past 3 decades, aquatic plants such as *Eichhornia crassipes* and *Pistia stratiotes* were used to enhance the effluent quality [17], [22]-[24]. The major characteristics of *E. crassipes* and *P. stratiotes* that made them as an attractive biological support medium for bacteria are the extensive root system and rapid growth rate [6], [18].

In spite of significant efforts worldwide towards the construction of artificial wetland system, it gained less attention due to the need of huge land requirement and capital investment from the government to build the new wastewater treatment plant using this method [1], [5], [25]-[27]. Developing an integrated eco-friendly wastewater treatment system based on artificial wetlands can be used to overcome

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problems in the industrial and domestic wastewater treatment plant [1], [5], [8], [28]-[30]. This system is known as the 'Integrated Phytogreen System' which mainly consists of phytoremediation and bioremediation of wastewater using aquatic plants [1], [5], [8], [17].

Domestic wastewater is the discharge water from the domestic resident, cities, restaurants and other commercial business. It is thus composed of human body wastes together with the water used for flushing, laundry, food preparation and the cleaning of kitchen utensils [31], [32]. It also needs to treat properly because it contains excessive nutrients, harmful bacteria, viruses and household chemicals that may contaminate the land and water of our state. This will threaten the public health [33], [34].

II. Materials and Methods

A. Materials

Two types of experiments were performed which is in-situ (at the site project) and ex-situ (in the laboratory). The selected aquatic plants were installed into the Phytogreen Zone (Z2) in the conventional oxidation pond located at Taman Anggerik Kempas, Johor Bahru Johor. The integrated phytogreen system consist of 3 major zone which are the influent zone (Z1), Phytogreen zone (Z2), Aeration zone (Z3), Inclined Plate Clarifier zone (Z3) and effluent zone (Z5).The aquatic plants growth in the Z2 were *Typha angustifolia* sp., *Lepironia articulata* sp., *Limnocharis flava* sp., *Monochoria vaginalis* sp., *Pistia stratiotes* sp., and *Eichhornia crassipes* sp.

Sample collections and handling procedures were performed according to the standard method for water and wastewater examination [35]. To ensure the objectives of the project achieved, the treatment process was monitored by 11 standard measurement parameters. The parameters used are temperature, pH, Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Suspended Solids (SS), Ammoniacal Nitrogen, Oil and Grease, Nitrate, Nitrite, Total Nitrogen, and Phosphorus levels in the control and treated sewage. In this paper only two main parameters were discussed which are BOD_5 and SS.

B. Collection of Sample

The collection of wastewater was carried out in several sampling points throughout the wastewater treatment plant. Fig. 1 shows the layout of integrated phytogreen system and 15 sampling points for this study.

The location of the wastewater sample was taken at the first oxidation pond called influent zone (Z1), which is namely the influent and after past through the hydraulic retention time (HRT) for 5 days. At this phase, domestic wastewater from all over the residential area at Taman Anggerik was channeled here. The wastewaters including domestic wastewater from kitchen, bath, laundry wastes, industrial establishments together with groundwater infiltration.

The next sample was from the second oxidation pond called maturation pond but it consists of 4 (four) main areas which is the Z2, Z3, Z4, and Z5. For each of the zones, several numbers of the wastewater sample were collected. Every sample from each location was recorded for analysis and monitoring for the future references. For the in-situ testing at each sampling points from S1, S2, S3 to S15 in integrated phytogreen system (IPS) the parameters was tested using the multiparameter water quality sonde or checker (Model YSI 6600 V2 – Environmental Monitoring System) and the data obtained was recorded accordingly.

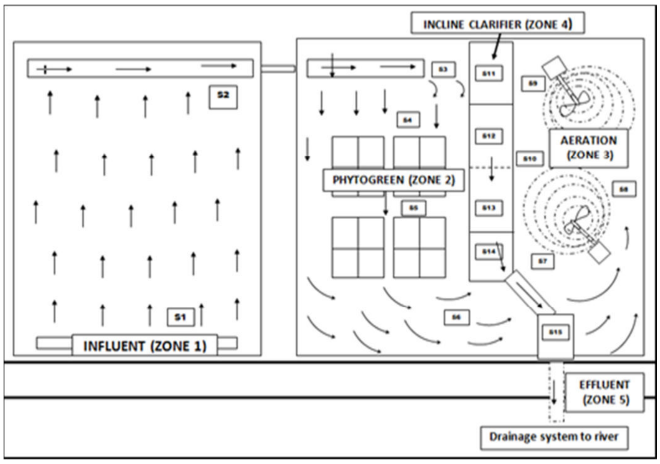

Fig. 1 Layout of integrated phytogreen system

C. Wastewater Characteristics and Quality of Sample

In data collections analysis, the domestic wastewater before and after treatment of the plants were analyzed for the characterized purpose. The ex-situ testing for each parameter is performed by using DR5000 - UV-Vis Spectrophotometer and colorimeters. The purposed is to determine the quality of the effluent discharge in study area comply the standard fixed by the Malaysia Water Quality Act (MEQA, 1974).

III. Result and Discussion

The analyzed detail results of the selected parameters were discussed. It is also discussed the two objectives of this study which are to identify the effectiveness of using aquatic plant (*Typha angustifolia* sp., *Lepironia articulate* sp., *Limnocharis flava, Monochoria vaginalis, Pistia stratiotes* sp. and *Eichhornia crassipes* sp,.) in the wastewater treatment process in order to comply standard A for effluent discharge and to distinguish the efficiency of wastewater treatment process using the aquatic plants (*Typha angustifolia* sp, *Lepironia articulata* sp., *Limnocharis flava, Monochoria vaginalis, Pistia stratiotes* sp. and *Eichhornia crassipes* sp.) in terms of several wastewater quality parameters.

The result of this experiment was analyzed using the Analysis of Variance (ANOVA) software. The analysis was based on One-Way ANOVA which involves one factor. This approach allows us to use sample data to identify if the values of three or more unknown population means are likely to be related or different.

A. Biochemical Oxygen Demand (BOD_5)

Biological Oxygen Demand (BOD) is the amount of the oxygen used by microorganisms in the oxidation of organic material in the water over a certain time and temperature [32], [34]. When a large quantity of organic waste present in the water supply there is a lot of bacteria present working to decompose the waste. In this case, the demand for oxygen was high (due to all the bacteria) [19], [26]. Thus, the BOD_5 level was high too. Fig. 2 shows the wastewater quality in Z1 which the BOD_5 in sampling point S1 and S2 were too high within the range of 100 mg/L to 520 mg/L.

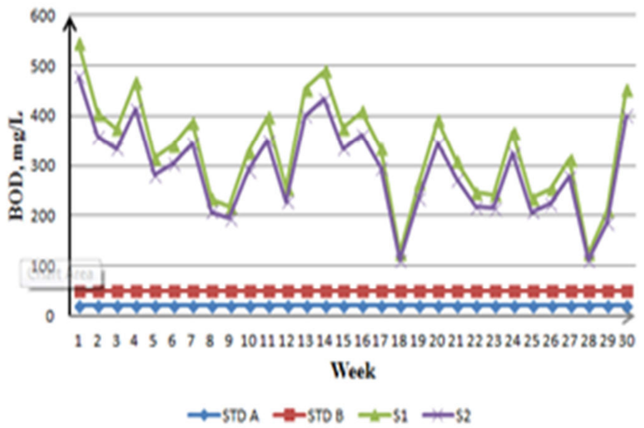

Fig. 2 Graph BOD5 vs Time (week) from W1 to W30

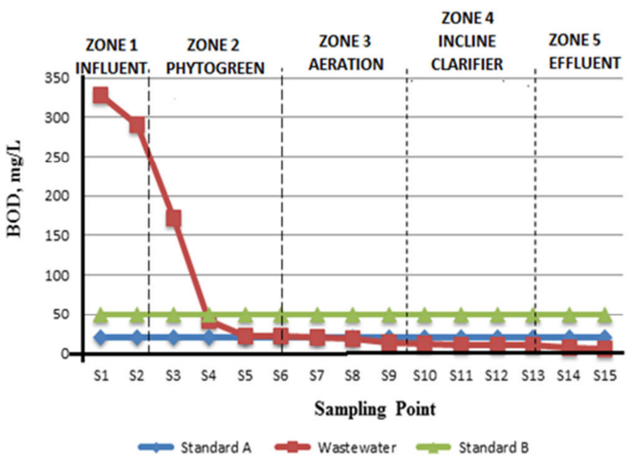

Fig. 3 Graph of BOD5 vs Sampling point (S1 to S15)

There is a lot of bacteria present working to decompose the waste. In this case, the demand for oxygen was high (due to all the bacteria).

Based on Fig. 3, the BOD level is decreasing throughout the graph. The wastewater from facultative pond enters the maturation pond which consists of the rest of 4 zones. The Z2 (Phytogreen zone) was started from point S3 to point S6. When wastewater from Z1 enter the IPS, the BOD_5 level was decreased drastically from S3 to S4 in Z2, while from S4 to S7 it was decreased gradually and begin consistently maintain in Z3, Z4 and Z5. From the graph, the Phytogreen area started with the highest value of the BOD_5 at the sampling point S3 which is about average 171.81 mg/L. The BOD is then reduced in value through point S4, S5, and S6 which are 40.49 mg/L, 22.23 mg/L, and 18.50 mg/L respectively. Fig. 4 shows the BOD_5 curve trend in Z2.

The BOD values ranged by the Environmental Quality Act (EQA) 1974 for Standard A is same and below 20 mg/L and Standard B is within the range of 20 – 50 mg/L. Based on the graph shown at Fig. 5, the BOD_5 value at point S15 is about average 6.00 mg/L and comply the Standard A for effluent discharge fixed by the MEQA, 1974.

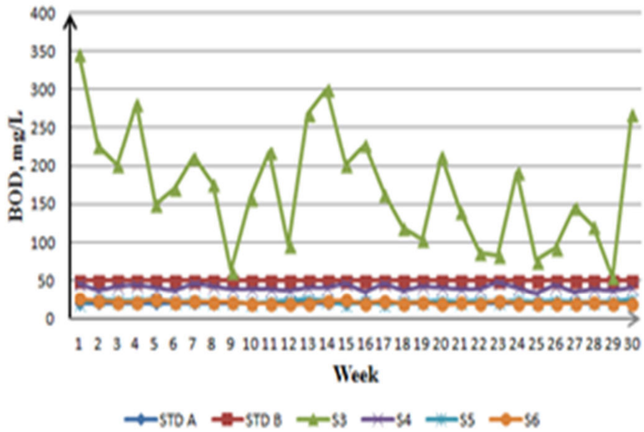

Fig. 4 Graph of BOD5 vs Week for Z2 (Phytogreen zone)

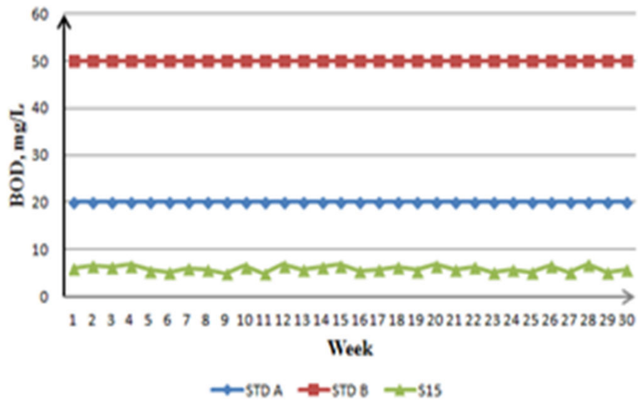

Fig. 5 Graph of BOD vs Week for Z5 (Effluent zone)

In order to support the finding, further statistical analysis was conducted through analysis of variance (ANOVA) using IBM SPSS Statistics Version 20. Before using ANOVA, the statistical hypothesis should be defined first. Null hypothesis, (H_0: $\mu_1 = \mu_2 = \mu_3 \ldots = \mu_{15}$) were defined as there are no significant difference in treatment between the BOD_5 value of the sample and the zone of the sample taken. In other words, all treatment produced is hypothesized to be equal. For the alternative hypothesis (H_1: $\mu_i \neq \mu_j$ for $i \neq j$) was defined as there are significant difference treatment between the BOD value of the sample and the zone of the sample taken or there is a treatment effect between each zone. The description $\mu_{1 \ldots}\mu_2$= Influent zone (Z1), $\mu_{3 \ldots}\mu_6$ = Phytogreen zone (Z2), $\mu_{7 \ldots}\mu_{10}$ =

Aeration zone (Z3), $\mu_{11...}\mu_{14}$ = Inclined plate clarifier zone (Z4) and μ_{15} = Effluent zone (Z5). (S1, S2: Influent, S3, S4, S5, S6: Phytogreen zone, S7, S8, S9, S10: Aeration zone, S11, S12, S13, S14: Incline plate clarifier zone, S15: Effluent).

TABLE I
SUMMARY OF ANOVA ANALYSIS FOR BOD5 IN Z2

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4860589	14	347185	211.679	$5x10^{-184}$	1.71456
Within Groups	713465	435	1640.15			
Total	5574054	449				

From Table I, the summary of the ANOVA analysis above, the P-value is $5x10^{-184}$ which is $P < 0.05$. This means that H_0 has been rejected. It reckons that there is a significant difference in treatment between the BOD_5 value and the zone of the sample taken. The percentage of BOD_5removal from the Phytogreen zone is 79.4%. The value proved that Z2 (Phytogreen zone) have the high capability to remove BOD_5 in IPS (Integrated Phytogreen system).

B. Suspended Solid (SS)

Suspended solids (SS) concentrations indicate the amount of solids suspended in the water, whether in mineral (e.g., soil particles) or organic (e.g., algae). However, the SS test measures the actual weight of material per volume of water, while the turbidity test measures the amount of light scattered from a sample (more suspended particles cause greater scattering). The difference is significant when estimating total quantities of material within or entering a stream [5], [8], [24].

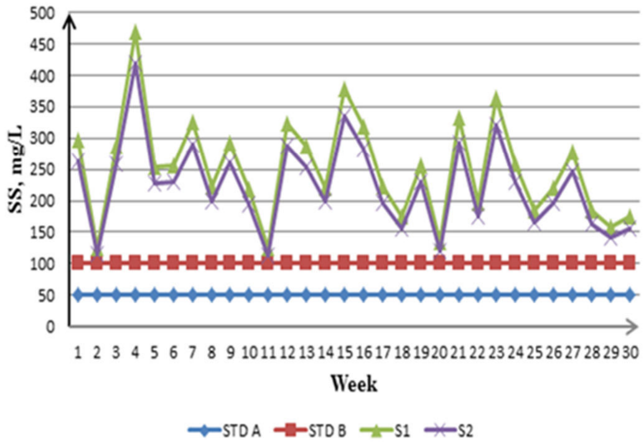

Fig. 6 Graph of SS vs Week for Z1 (Influent zone)

Based on the graph shown in Fig. 6, the data from S1 and S2 in Z1 were very high which is out of the range of standard B for MEQA 1974. The range of S1 and S2 recorded in Z2 are 120 mg/L to 450 mg/L. It was happen because the sludge in facultative pond in this study, actually already full due to no maintenance done for dislodging the pond since 30 years ago and addition the cost involves for dislodging is very high. When the wastewater from Z1 (influent zone) at sampling point S2 enter the maturation pond at sampling points S3, it shows that the SS data decrease drastically to 110.05 mg/L. Fig. 7 shows the phenomenon of this trend.

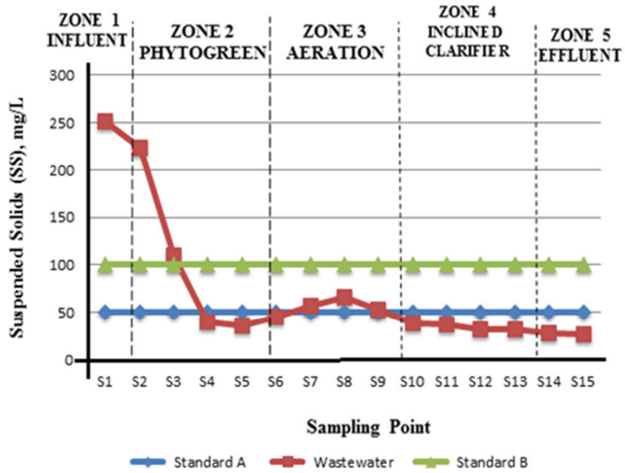

Fig. 7 Graph of SS vs Sampling point (S1 to S15)

Based on the graph shown in Fig. 7 also indicate that the overall value of SS is decreasing throughout the experiment. In the Z2 (Phytogreen zone), the highest value of the SS is at point 3, 110.05 mg/L. Then it declined through point S4, and S5 with 39.15 mg/L and 35.75mg/L respectively. For point S6, the SS value is slightly increased to 44.71 mg/L as it close to the Z3 (aeration zone). From the result, it can be concluded that the selected aquatic plant used is efficient and have a big potential to remove the suspended in Z2.

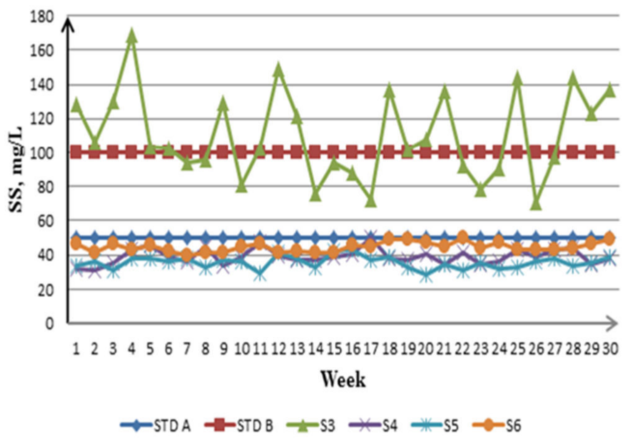

Fig. 8 Graph of SS vs Week for Phytogreen zone

Meanwhile, Fig. 8 shows the SS in Z2 (phytogreen zone) vs time in 30 weeks interval time, indicated that the SS in S3 shows fluctuated data between the range of 68 mg/L to 170 mg/L. But for the sampling point S4, S5 and S6 in Z2 were consistently comply the standard A fixed by MEQA 1974. It is strongly proved that when the wastewater from Z1 pass through the Z2 until sampling point S6, its indicated that the wastewater treated by aquatic plants mentioned earlier in Z2 was successfully comply the standard A before enter the Z3 (aeration zone) in integrated phytogreen system (IPS).

Malaysia Environmental Quality Act (MEQA) 1974 fixed the ranged of SS value for Standard A is same and below 50 mg/L meanwhile for the standard B is between 50 and 100 mg/L. Based on the graph shown in Fig. 9, its shows that the SS value at the effluent located at S15 with average of 25.93 mg/L and comply the Standard A for effluent discharge fixed by MEQA 1974.

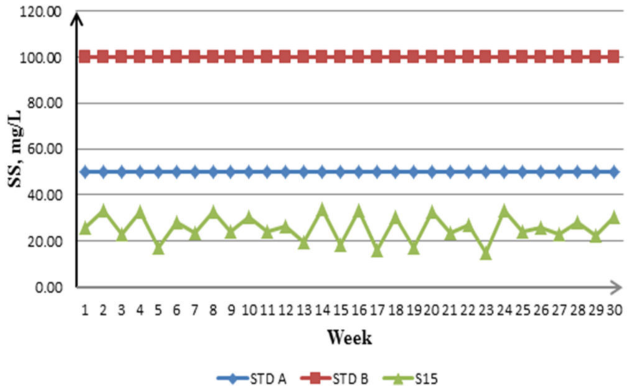

Fig. 9 Graph of SS vs Week for Z5 (Effluent Discharge)

For above analysis, the null hypothesis (H_0: $\mu_1 = \mu_2 = \mu_3 \ldots = \mu_{15}$) were representing no significant different treatment between the value of suspended solids and the zone of the sample taken. In other words, all treatment produce is equal. The alternative hypothesis (H_1: $\mu_i \neq \mu_j$ for $i \neq j$) were described as there is a significant treatment effect between each zone. The description $\mu_{1}\ldots\mu_{2}$, $\mu_{3}\ldots\mu_{6}$, $\mu_{7}\ldots\mu_{10}$, $\mu_{11}\ldots\mu_{14}$ and μ_{15} is influent zone, phytogreen zone, aeration zone, inclined plate clarifier zone and effluent zone respectively. (S1, S2: Influent zone; S3, S4, S5, S6: Phytogreen zone; S7, S8, S9, S10: Aeration zone; S11, S12, S13, S14: Incline plate clarifier zone and S15: Effluent).

TABLE II
SUMMARY OF ANOVA ANALYSIS FOR SS IN Z2

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2108045	14	150575	177.4	1×10^{-169}	1.71456
Within Groups	369222	435	848.786			
Total	2477266	449				

From Table II above, the P-value is 1×10^{-169} which is lower than 0.05. Therefore, the H_0 is rejected. It can be concluded that there is a significant different treatment between the value of suspended solids in the sample and the zone of the sample taken. The percentage of removal from the Phytogreen zone is 75.82%. Thus, Z2 has proven the ability of suspended solids removal.

IV. CONCLUSION

Conducted research has shown that aquatic plants found in phytogreen zone (Z2) have been successfully removed the BOD_5 and SS in an integrated phytogreen system (IPS) which were able to remove 79.4% and 75.82% respectively. Thus, in this study it was found that the phytogreenzone (Z2) have a big potential to remove the physical and biological constituents as a green technology solution in integrated phytogreen system.

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REFERENCES

[1] A.R. Abdul Syukor, A.W. Zularisam, Z. Ideris, M.I. Mohd. Said, S. Sulaiman, "Treatment of Industrial Wastewater at Gebeng Area Using *Eichornia crassipes* sp. (Water Hyacinth), *Pistia stratiotes* sp. (Water Lettuce) and *Salvinia molesta* sp. (Giant Salvinia)," Adv. Environ. Biol., vol. 7, no. October Special Issue 2013, pp. 3802–3807, 2013.
[2] C.W.N. Anderson, R.R. Brooks, A. Chiarucci, C.J. LaCoste, M. Leblanc, B.H. Robinson, R. Simcock, and R.B. Stewart. Phytomining for Nickel, Thallium and Gold, Journal of Geochemical Exploration, 67, 1-3, 407-415, ISSN: 0375-6742, 1999.
[3] F. Braceros Michelle. A Review Article on Phytoremediation and A Citizen's Guide to Bioremediation, April 1996, EPA 542-F-96-007, 2009.
[4] M.T. Cooke. Phytoremediation: Using Plants to Remediate Groundwater Contaminated with Trichloroethylene (TCE). State College, PA: Pennsylvania State University, 1999.
[5] A. Syukor, A. Wahid, M. Ismid, and S. Sulaiman, "Treatment of Industrial Wastewater in Gebeng Area, Kuantan Pahang Using Phytogreen System," Energy Educ. Sci. Technol. Part A. Energy Sci. Res., vol. 32, no. 1, pp. 347–354, 2014.
[6] M. A. Rahman and H. Hasegawa, "Aquatic Arsenic: Phytoremediation Using Floating Macrophytes," Chemosphere, vol. 83, no. 5, pp. 633–46, Apr. 2011.
[7] P. C. Abhilash, S. Jamil, and N. Singh, "Transgenic Plants for Enhanced Biodegradation and Phytoremediation of Organic Xenobiotics" Biotechnol. Adv., vol. 27, no. 4, pp. 474–88, 2009.
[8] A. Syukor, A. Wahid, I. Zakaria, M. Ismid, S. Sulaiman, A. Halim, and D. L. Thomas, "Potential of Aquatic Plant as Phytoremediator for Treatment of Petrochemical Wastewater in Gebeng Area , Kuantan," Adv. Environ. Biol., vol. 7, pp. 3808–3814, 2013.
[9] A. Tewari, R. Singh, N.K. Rai. Amelioration of Municipal Sludge by *Pistia stratiotes* L.: Role of Antioxidant Enzymes in Detoxification of Metals. Ecotoxicology and Bioremediation, National Botanical Research Institute, Rana Pratap Marg, Lucknow 226 001, India, 2008.
[10] R.K. Trivedy. Use of Aquatic Plants in wastewater treatment. P.164-183 in: Low Cost Wastewater Treatment Technologies. D publishers, Jaipur, 2001.
[11] J. L. Bankston, D. L. Sola, A. T. Komor, and D. F. Dwyer, "Degradation of Trichloroethylene in Wetland Microcosms Containing Broad-Leaved Cattail and Eastern Cottonwood.," Water Res., vol. 36, no. 6, pp. 1539–46, Mar. 2002.
[12] C. Mant, S. Costa, J. Williams, and E. Tambourgi, "Phytoremediation of Chromium by Model Constructed Wetland," Bioresour. Technol., vol. 97, no. 15, pp. 1767–72, Oct. 2006.
[13] S. Sulaiman, A.S. Abd.Razak, A. Nor-Anuar, S. Chelliapan, "A Study of Using *Allium cepa* (Onion) as Natural Corrosion Inhibitor in Industrial

Chill Wastewater System," Res. J. Chem. Sci., vol. 2, no. 5, pp. 1–7, 2012.
[14] D. Zhang, R. M. Gersberg, and T. S. Keat, "Constructed Wetlands in China," Ecol. Eng., vol. 35, no. 10, pp. 1367–1378, Oct. 2009.
[15] A. K. Kivaisi, "The Potential for Constructed Wetlands for Wastewater Treatment and Reuse in Developing Countries: A Review," Ecol. Eng., vol. 16, no. 4, pp. 545–560, Feb. 2001.
[16] M. G. Healy and C. J. O' Flynn, "The Performance of Constructed Wetlands Treating Primary, Secondary and Dairy Soiled Water in Ireland (A Review)," J. Environ. Manage., vol. 92, no. 10, pp. 2348–54, Oct. 2011.
[17] A. Syukor and S. Sulaiman, "Treatment of Industrial Wastewater Using *Eichornia crassipes*, *Pistia stratiotes* and *Salvinia molesta* in Phytogreen System," Energy Educ. Sci. Technol. Part A. Energy Sci. Res., vol. 32, no. 1, pp. 339–346, 2014.
[18] Y. Zimmels, F. Kirzhner, and a Malkovskaja, "Application of *Eichhornia crassipes* and *Pistia stratiotes* for Treatment of Urban Sewage in Israel.," J. Environ. Manage., vol. 81, no. 4, pp. 420–8, Dec. 2006.
[19] A. Nesterenko-Malkovskaya, F. Kirzhner, Y. Zimmels, and R. Armon, "*Eichhornia crassipes* Capability to Remove Naphthalene from Wastewater in the Absence of Bacteria," Chemosphere, vol. 87, no. 10, pp. 1186–91, Jun. 2012.
[20] N. Jafari. Ecological and Socio-Economic Utilization of Water Hyacinth (*Eichhornia crassipes* Mart Solms). Department of Biology, Faculty of Basic Sciences, University of Mazandaran, Babolsar, Iran, 2010.
[21] K. Chunkao, C. Nimpee, and K. Duangmal, "The King's Initiatives Using Water Hyacinth to Remove Heavy Metals and Plant Nutrients from Wastewater through Bueng Makkasan in Bangkok, Thailand," Ecol. Eng., vol. 39, pp. 40–52, Feb. 2012.
[22] J. S. Weis and P. Weis, "Metal Uptake, Transport and Release by Wetland Plants: Implications for Phytoremediation and Restoration," Environ. Int., vol. 30, no. 5, pp. 685–700, Jul. 2004.
[23] B. S. Smolyakov, "Uptake of Zn, Cu, Pb, and Cd by Water Hyacinth in the Initial Stage of Water System Remediation," Appl. Geochemistry, vol. 27, no. 6, pp. 1214–1219, Jun. 2012.
[24] A.D. Karathanasis, C.L. Potter, M.S. Coyne. Vegetation Effects on Faecal Bacteria, BOD, and Suspended Solid Removal in Constructed Wetlands Treating Domestic Wastewater. Ecol. Eng. 20:157-169, 2003.
[25] Y. Zimmels, F. Kirzhner, and A. Malkovskaja. "Application of *Eichhornia crassipes* and *Pistia stratiotes* for Treatment of Urban Sewage in Israel," Journal of Environmental Management, vol. 81, no. 4, pp. 420–428, 2006.
[26] K.R. Reddy. "Fate of Nitrogen and Phosphorus in a Waste-Water Retention Reservoirant Containing Aquatic Macrophytes," Journal of Environmental Quality, vol. 12, no. 1, pp. 137–141, 1993.
[27] D.M.M. Mbuligwe, D. A. Mashauri, and B. S. Abdulhussein. "Constructed Wetland at the University of Dar es Salaam," Water Research, vol. 34, no. 4, pp. 1135–1144, 1997.
[28] M.A. Maine, N.L Sune, & S.C Lagger. Chromium Bioaccumulation: Comparison of the Capacity of Two Floating Aquatic Macrophytes. Water Research, 38(6), 1494-1501, 2004.
[29] C.P. Kaushik, S. Eapen, S. Singh, V. Thorat, K. Raj, and S. F. D'Souza. Phytoremediation of Radiostrontium (90Sr) and Radiocesium (13 7Cs) Using Giant Milky Weed (*Calotropis gigantea* R.Br.) Plants. Chemosphere 65: 2071-2073, 2010.
[30] R.H. Kadlec, R.L. Knight, J. Vymazal, H. Brix, P. Cooper, and R. Habert. Constructed Wetlands for Pollution Control: Processes, Performance, Design and Operation. London, IWA Publishing, 156 P.ISBN 1900222051, 2000.
[31] L. Jacobs L and W.R. Berti, Chemistry and Phytotoxicity of Soil Trace Elements from Repeated Sewage Sludge Applications. – J. Environ. Qual. 25; 1025-1032, 1996.
[32] F.B. Green, I. Tadesse, and J. A. Puhakka, "Seasonal and Diurnal Variations of Temperature, pH and Dissolved Oxygen in Advanced Integrated Wastewater Pond System Treating Tannery Effluent," Water Research, vol. 38, no. 3, pp. 645–654, 2004.
[33] C.P.L. Grady, and H.C. Lim. Biodegradation of Toxic Organic: Status and Potential Biological Wastewater Treatment. Marcel Dekker, NY, 1980.
[34] R. Burk and H. Levander. In: Selenium in Modern Nutrition in Health and Disease, pp. 242. (Shils M. E., Olson J. A., Shike M., Eds.). London, Lea and Febiger Press, 1994.
[35] APHA (American Public Health Association), AWWA (American Water Works Association), and WPFC (Water Pollution Control Federation). 2005. Standard Methods for the Examination of Water and Waste Water, American Public Health Association, Wash, USA, 19th edition.