Application of Phyto-Technology for Reducing BOD_5 and TSS in Septage Treatment: Laboratory Trials from Nigeria

E. A. Oluwadamisi, [1*] M. K. C. Sridhar[2], A. O. Coker, [1] , S. O. Jacob[3]

[1*]Civil Engineering Department, Faculty of Technology, University of Ibadan, Nigeria

[1]Civil Engineering Department, Faculty of Technology, University of Ibadan, Nigeria

[2]Department of Environmental Health Sciences, Faculty of Public Health, College of Medicine, University of Ibadan, Nigeria

[3]Civil Engineering Department, Faculty of Engineering and Technology, University of Ilorin, Nigeria

ABSTRACT

The diversity of aquatic plants having varied and unique phytoremediation potentials plays a vital role in the treatment of different types of wastewater. Several developing countries including Nigeria still employ the use of septic tanks and soak-away-pit for handling wastewater containing faecal matter. These practices of handling wastewater generate high septage. Septage are evacuated wastewater which is highly organic. To treat wastewater rich in BOD_5 and TSS, requiring appropriate treatment before discharge into the receiving bodies. Application of Phyto-technology for reduction of septage BOD_5 and TSS using macrophytes such as Typha latifolia, Phragmites australis and using them under poly-culture in varied water to septage dilution was compared. Maximum removal efficiency of BOD_5 and TSS revealed Phragmites, Typha-Phragmites Poly-culture and Typha alone to be efficient in this order. Phragmites showed 98% and 97% of BOD_5 and TSS removal. In the undiluted wastewater, the aquatic plant grew only at 80% efficiency. Effective septage management is achievable on a relatively low-cost, environmentally friendly and requiring low maintenance using locally available aquatic plants.

Key words: Septage, Wastewater, Municipal waste, Effluent quality

1. INTRODUCTION

In most developing countries, the use of septic tanks and soak-away-pits for handling wastewater or septage is still a common practice. However, inadequate planning, poor construction, maintenance and methods of evacuation of its content into waterways have led to environmental pollution with its associated health problems in developing countries such as Nigeria. Wastewater can be classified as low, medium and high strength with respect to organic loading. Septage represents complex water-carrying waste of high organic loading which needs to be safely disposed. The treatment of septage generated from households is aimed at reducing or eliminating its harmful components which has negative impact on humans and the immediate environment. Abbasi and Abbasi (2010) noted that several wastewater treatment technologies have been designed and operated to handle varying volumes of wastewater. These technologies are classified as physical, chemical, biological and some of them are aquatic, or terrestrial systems. Researches were also carried out where these systems are operated on full or pilot and laboratory scale. The extent and level of treatment required for wastewater is dependent on its level of pollution, organic loading and the usage of its final effluent (Omenka, 2010; Abdullahi, et al., 2013).

Mahmood, et al (2005) opined that the use of aquatic plants for phytoremediation of wastewater is suitable for developing countries, as they are cheaper to construct, maintain and requires little operational skills. Similarly, Anning, et al (2013) considered phytoremediation as the most sustainable wastewater treatment option for tropical developing countries. Studies have confirmed that in aquatic wastewater treatment systems, floating aquatic weeds are low-cost powerful bio agents which purify wastewater lying under them through physical, chemical and biological actions (Abbasi and Abbasi, 2010).

Phytoremediation processes over the years has been applied to effectively handle various environmental degradation challenges such as wastewater disposal, soil remediation and sediments removal. It utilizes the potentials of the emerging aquatic plants to decontaminate the wastewater in a manner that is comparatively cheap, qualitatively acceptable and environmentally friendly (Garbisu, et al., 2002; Hegazy, et al., 2011; Nouri, et al., 2011; Verma, et al.,

2014). In phyto-reduction, the removal of wastewater constituents are achieved through several processes such as sedimentation, filtration, chemical precipitation, adsorption, microbial interactions, and uptake of vegetation. Phytoremediation strategies using constructed wetland technology has proved to be most effective aquatic wastewater treatment system (Aluko and Sridhar, 2005; Badejo et al., 2012; Gupta, et al., 2012; Achi, et al., 2014).
The effectiveness of Phyto-reduction is dependent on identification/selection and utilization of efficient aquatic plants; uptake capacity of dissolved nutrients and metals by the growing plants; harvest and beneficial use of the plant biomass produced from the remediation system. The nutrient removal potentials and accumulation of pollutants vary from plant to plant and also from specie to specie within a genus. Hence, the selection of aquatic plant with high nutrient uptake potential is paramount, ensuring the growth and development of such plant in a controlled manner and in quantitatively propagated dispersion in the Phyto-reduction processes is essential (Singh, et al., 2003; Lu, 2009; Stefani, et al., 2011 and Gupta, et al., 2012).

Over the years, *Typha latifolia* and *Phragmites australis* have been studied as effective plants for phyto-reduction. According to Vymazal (2007), Typha are often part of natural and constructed treatment wetland ecosystems. In wastewater treatment, Typha has been employed either in primary or secondary treatment process for domestic, agricultural and industrial wastewater (Scholz and Xu, 2002). Phytoremediation potentials of *Typha* for industrial effluent was studied in which Rhizofiltration was found to be responsible for reducing pollutants in the effluents. Rhizofiltration was defined as the removal of aqueous pollutants by the plant root system (Dushenkov 1995; Hegazy, et al., 2011).

According to Srivastava, et al (2014), the genus *Phragmites* has proven to have the ability and potential to mitigate or remove pollutants from wastewater and the environment. Vipat, et al (2008) also pointed out that their extensively deep root system (0.75m) and rhizomes with large numbers of rhizosphere per unit surface helps the plant in nutrient uptake. Similarly, Todorovics, et al (2005) presented that Phragmites aquaculture produced wastewater effluent of similar quality as the conventional treatment methods.

Typha latifolia and *Phragmites australis* were the only successfully established plants applied for the treatment of tannery wastewater on an experimental pilot units located at a leather Company in the north of Portugal. Their COD and BOD removal efficiency ranged from 41% to 67% for hydraulic loading rate (HLR) of 3cm/d, from 54% to 73% for 6cm/d respectively. Also, their TSS removal efficiency varies from 48% to 92% for HLR of 3cm/d and between 62% and 77% for 6cm/d (Calheiros, et al., 2007). According to Hossien and Mohsen (2014), Typha and Phragmites poly-culture planted in a surface lagoon system has the ability to remove nitrate and phosphorus while increasing dissolved oxygen and pH of the water.

Many cities in developing countries lack appropriate wastewater treatment facilities while available ones are not functional or fully operational. The Satellite towns of Abuja, the Federal Capital Territory of Nigeria lack these wastewater treatment facilities, hence they resort into construction of soak-away and septic tanks for their wastewater management (Oluwadamisi, 2013). Soak-away and septic tanks for wastewater management from households has led to the generation of septage with high concentration of BOD_5 and TSS loading. When these septic tanks are filled up, their contents are evacuated and indiscriminately discharged into the environment. Hence, there is need to evolve a functional, acceptable and environmentally friendly septage treatment system with low construction, operation and maintenance costs. This study aimed at investigating and comparing the potential of Typha and Phragmites aquatic plants in the removal BOD_5 and TSS from septage on a laboratory scale.

2. MATERIALS AND METHODS

2.1 Experimental Site: This study was carried out at Wupa Basin Sewage Treatment Facility in Abuja, the Federal Capital City of Nigeria. It is pertinent to note that Abuja has tropical climate with average annual rainfall ranging from 1100mm to 1600mm with an accompanying maximum temperature ranging from 30.4°C to 35.1°C due to dense cloud cover (Medugu, 2009; Aondoakaa, 2012). The Federal Capital Territory (FCT), Abuja is well drained with two main rivers flowing within its vicinity. Gurara and Usman Rivers flowing northwest and northeast directions, respectively. The experimental site housed the Abuja Central Sewerage Treatment Plant with Wupa River as the receiving body of the treated effluent.

2.2 Experimental Setup: Typha and Phragmites plants were harvested from Jabi Lake in Abuja. Bed materials of gravel, sand and a well prepared bed in a 100L plastic container as shown in Figure 1(a, b and c) was set up. Ten (10) healthy off-shoots of Typha, Phragmites and Five (5) each of combined Typha-Phragmites Poly-culture with an average weight of 97.32, 329.92 and 198.62g respectively were transferred into the experimental containers to study their nutrient removal potential and efficiency in different septage concentrations. These were prepared and planted in the prepared gravel-sand bed as shown in Figure 2. Samples of evacuated septage were collected from emptier truck discharging into Manhole MH-32 located along Ring Road II of the Federal Capital City. Samples were reconstituted into ratio of 1:1 (20L septage to 20L water) and an undiluted sample. A volume of 40 L of each reconstituted samples were introduced into the treatment beds and the samples were labeled appropriately:

i. Treatment I: This consisted of 40 L of septage introduced into the plot with 10 healthy offshoots of *Typha latifolia* only.

Sample A_T: contains undiluted septage sample planted with Typha

Sample B_T: contains septage diluted with water in the ratio of 1:1 (i.e. 20 L of septage diluted with 20 L of tap water).

ii. Treatment II: this represents septage 40 L and10 healthy offshoots of *Phragmites australis* only.

Sample A_P: contains undiluted septage sample planted with Phragmites

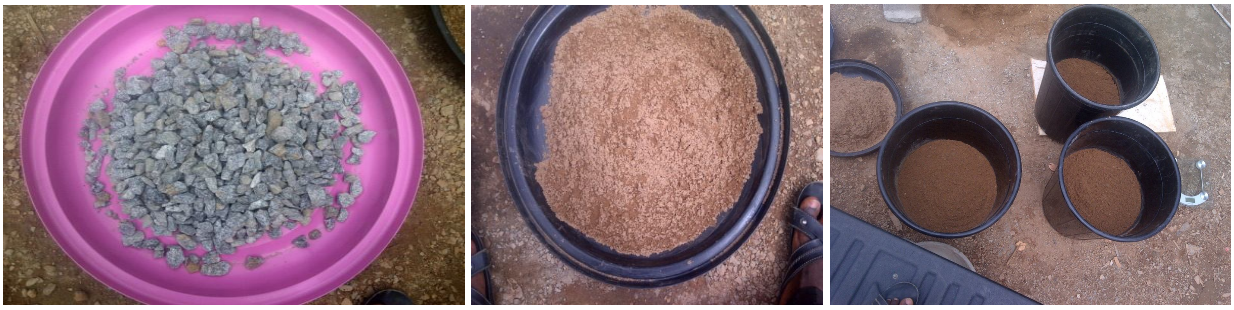
Sample B_P: contains septage diluted with water in the ratio of 1:1 (20 L of septage and 20 L of tap water) planted with Phragmites.

iii. Treatment III: This represents septage 40L with 5 healthy offshoots *Typha and 5 Phragmites plants* to make ten (10) poly-culture offshoots.

Sample A_{TP}: contains undiluted septage sample planted with Typha-Phragmites ploy-culture

Sample B_{TP}: contains septage diluted with water in the ratio of 1:1 (20 L of septage and 20 L of water) planted with a combination of Typha and Phragmites in the same ratio.

Standard laboratory wastewater analysis were carried out as stipulated in the American Public Health Association (APHA, 1998) and American Water Works Association (AWWA, 1998) standard to test for BOD_5 and Total Suspended Solids, TSS of septage for a 2weeks period. Respirometric and Gravimetric methods were adopted in measuring BOD_5 and TSS respectively.



a) Gravel (10-15mm) *b) Sand (0.1-2mm)* *c) Prepared bed*

Figure 1: Materials used for experimental phyto-bed preparation and the beds as they appear

a) *Typha latifolia* b) *Typha and Phragmites* c) *Phragmites australis*

Figure 2: Aquatic plants transferred into the prepared beds

2.3 Treatments and Analytical Procedures: Initial septage characteristics was determined by taking a grab sample of each dilutions for laboratory analysis. Also, daily grab samples from each dilutions were taken for laboratory analysis for BOD_5 and TSS using respirometric and gravimetric method of analysis respectively. The results were compared with initially determined septage concentration to evaluate the rate of removal of BOD_5 and TSS.

3. RESULTS AND DISCUSSION

The initial septage characteristics was determined using appropriate water and wastewater laboratory analysis procedures is as shown in Table 1 (APHA, 1998).

Table 1: Initial septage characteristics of measure parameters

		Septage Parameters (mg/L)									
Samples	Location	BOD_5	TSS	NH_4^+-N	PO_4^{2-}	pH	DO	Temp (^{0}C)	TN (mg/L)	TP (mg/L)	Total Coli-form (No/100mL)
1	Berger Yard, Wuse	330.00	745.00	28.00	19.15	6.86	2.82	25.9	45	10.25	3000
2	Gwarinpa I	170.00	1190.00	28.00	17.35	6.98	1.85	25.6	45	9.65	3000
3	Berger Yard, Idu	450.00	2500.00	25.65	21.50	6.54	1.50	26.5	40.5	12.1	>5000.00
4	Garki II	750.00	3000.00	30.05	26.90	7.14	0.80	26.9	45	12.7	>5000.00
5	Wuye District	700.00	3000.00	28.05	30.00	7.5	0.80	25.5	53	18.6	>5000.00
6	Dantata Yard, Garki II	500.00	2970.00	29.00	32.50	6.59	1.00	25.6	50	17.7	>5000.00
	Minimum	170.00	745.00	25.65	17.35	6.54	0.80	25.50	40.50	9.65	3000.00
	Maximum	750.00	3000.00	30.05	32.50	7.50	1.85	26.90	53.00	18.60	3000.00
	Average	483.33	2234.17	28.13	24.57	6.94	1.19	26.00	46.42	13.50	3000.00
	Standard Deviation	219.61	1009.26	1.46	6.14	0.36	0.47	0.57	4.41	3.79	>5000.00
WHO	**Permissible Limit (mg/L)**	**30.00**	**30.00**	**10.00**	**5.00**	**6.0-9.0**	**NS**	**<40**	**10.00**	**5.00**	**400.00**
FEPA/NESREA		**50.00**	**25.00**	**1.00**	**5.00**	**6.0-9.0**	**>2.00**	**<40**	**10.00**	**2.00**	**400.00**

3.1 Nutrient removal efficiencies of the plants from undiluted septage

The rate of nutrient removal and overall efficiency of the plants used for Phyto-reduction of BOD_5 and TSS from a given septage dilution were compared and presented in Table 2.

Reduction of Septage BOD_5 (0% dilution septage): Phragmites proved to be the highest in BOD_5 removal. The efficiency removal of BOD_5 in the undiluted septage sample is 92, 89 and 88% for Phragmites, Typha and Typha-Phragmites poly-culture respectively. The plants also removed TSS with 98% efficiency.

Table 2: Rate of BOD_5 and TSS removal using different Plants in 0% septage dilution

	BOD_5 (mg/L)			**TSS (mg/L)**		
Aquatic Plant	Typha	Phragmites	Typha-Phragmites	Typha	Phragmites	Typha-Phragmites
Time (Day)						
0	**170.00**	**170.00**	**170.00**	**1196.00**	**1203.00**	**1190.00**
1	160.00	90.00	165.00	383.00	462.00	400.00
2	140.00	85.00	158.00	313.00	380.10	385.00
3	135.00	75.00	150.00	245.00	298.50	300.00
4	125.00	72.50	145.00	175.00	217.00	282.00
5	90.00	70.00	90.00	105.50	135.00	239.00
6	85.00	66.00	120.00	83.20	110.75	200.00
7	80.00	60.00	100.00	61.00	79.00	189.00
8	73.00	53.00	86.00	39.00	50.20	70.10
9	70.00	45.00	78.00	18.00	22.00	16.30
10	60.00	36.00	74.00	35.00	22.00	10.00
11	35.00	25.00	60.00	28.00	22.00	18.20
12	20.00	15.00	40.00	26.00	22.00	21.50
13	18.50	14.00	21.00	25.80	21.50	21.00
14	18.00	13.50	20.05	20.50	21.00	20.00

3.2 Effect of dilution of the septage on the Nutrient removal efficiency

The rate of nutrient removal and the overall efficiency of the plants used for BOD_5 and TSS removal from a given septage dilution were compared and presented in Table 3.

Reduction of Septage BOD_5 (50% septage dilution): Phragmites revealed highest efficiency of 89% for BOD_5 removal followed by 83% and 78% for Typha-Phragmites poly-culture and Typha respectively.
Reduction of Septage TSS (50% septage dilution): Typha-Phragmites poly-culture revealed highest efficiency of 98% while Phragmites and Typha showed 97% each.

Table 3: Removal rate of BOD_5 and TSS using different plants in 50% septage dilution

Nutrient	**BOD_5 (mg/L)**			**TSS (mg/L)**		
Aquatic Plant	Typha	Phragmites	Typha-Phragmites	Typha	Phragmites	Typha-Phragmites
Time (Day)						
0	**130.00**	**135.00**	**132.00**	**650.00**	**650.00**	**651.00**
1	122.40	128.00	127.00	501.00	500.00	220.00
2	112.00	114.00	118.00	450.00	435.00	190.00
3	101.50	98.50	110.00	365.50	356.50	165.00
4	91.50	82.00	100.50	301.00	299.00	140.50
5	82.00	70.00	92.00	220.00	230.00	100.50
6	70.80	52.00	85.50	140.50	160.50	78.50
7	60.00	40.80	76.20	80.00	100.00	50.50
8	55.00	32.00	69.50	53.00	49.50	37.00
9	52.00	25.00	63.90	25.60	35.00	24.00
10	46.00	22.00	58.40	23.00	20.00	10.90
11	40.70	18.50	46.00	21.05	22.00	10.60
12	36.60	16.30	35.50	18.80	17.00	10.40
13	30.00	16.00	24.00	18.00	16.90	10.10
14	28.20	15.50	22.10	16.80	16.50	10.00

3.3 Control Sample: The control sample consisted of 40L of undiluted septage sample setup in a 50L experimental container without an aquatic plants. This served as control for the various planted cultures. Details of the experimental setup is as shown in Table 4.

Table 4: Removal rate of BOD_5 and TSS in the Unplanted and Undiluted control septage sample

Day	BOD	TSS
0	170.00	1190.00
1	145.20	555.70
2	136.80	500.00
3	128.50	444.00
4	120.00	388.50
5	112.00	330.50
6	102.50	275.00
7	95.00	220.00
8	92.00	172.80
9	89.40	125.00
10	86.50	78.50
11	85.50	74.00
12	84.00	70.10
13	83.50	65.50
14	82.40	62.75

3.4 Effect of septage on the growth characteristics of the plants

3.4.1 Plants' growth in undiluted septage

Typha latifolia thrived well with increase in the number of plant offshoots/stems from 10 to 23 numbers and the leaves increased from 28 to 56 numbers within two weeks of the experiment. This agrees with the report of Debing et al (2009) in which a poly-culture vegetation structure of Typha-Phragmites-Scirpus macrophytes, (with Typha as major species) and Typha-monoculture vegetation as three design treatments were planted in pilot-scale gravel-based subsurface wetlands to treat artificial sewage. *Typha* vegetation increased in offshoots and stems while depicting high nutrient removal (Table 5).

3.4.2 Plants' growth in diluted septage

Typha latifolia did not thrive very well as there was no increase in the numbers of offshoots/stems. However, the leaves/stems increased from 26 to 46 within 2weeks of the experiment. The growth pattern and subsequent nutrient removal of *Typha latifolia* is in consonance with the findings of Baskar, et al (2014) in which two pilot units planted with Typha and Phragmites were operated in batch mode receiving pretreated campus domestic wastewater.

Table 5: Growth pattern of aquatic plants in different dilution scenario

S/N	Percentage Dilution	Plants	Growth (Numbers after 2 weeks) Offshoots/Stems 0 day After 14 days	Leaves 0 day After 14 days
1	Undiluted Septage (0%)	Typha	10 to 23	28 to 58
		Phragmites	10 to 18	28 to 56
		Typha-Phragmites Poly-culture	10 to 23	32 to 72
2	50% Dilution (ratio 1:1 water to septage)	Typha	10 to 10	26 to 46
		Phragmites	10 to 10	25 to 57
		Typha-Phragmites Poly-culture	10 to 14	36 to 64

4. CONCLUSION AND RECOMMENDATION

The results of this study revealed that Phyto-reduction using Typha, Phragmites and Typha-Phragmites Poly-culture are effective for septage treatment. The plants thrived well in septage of high organic loading. The BOD_5 and TSS removal efficiencies of the plants are higher in undiluted septage and also promotes effective growth rate of plants, hence ensuring establishment of the aquatic plants for further nutrient removal. Septage is rich in organic matters and contains high concentration of BOD_5 and TSS of which its dilution reduces the nutrient concentrations. The cultured aquatic plants in diluted samples revealed lower growth rate in comparison with undiluted samples. *Phragmites australis* shows better capacity for removal of BOD_5 with 92% and 89% efficiency in undiluted and 50% dilution samples respectively. Typha-Phragmites Poly-culture proved to be more efficient in TSS removal with 98% efficiency in the undiluted and diluted samples respectively.

REFERENCES

[1] Abbasi, S. A. and Abbasi, T. “Factors which facilitate wastewater treatment by aquatic weeds the mechanism of the weeds’ purifying action,” Inter. J. Environ. Studies, 67, pp. 349-371, 2010.

[2] Abdullahi, I. N., Aliyu, H. K., and Musa, D. “The challenges of domestic wastewater management in Nigeria: A case study of Minna, central Nigeria,” International Journal of Development and Sustainability, 2(2), pp. 1169-1182, 2013.

[3] Achi, C. G., Sridhar**,** M. K. C. and Coker, A. O. “Performance Evaluation a Water Hyacinth Based Institutional Waste Treatment Plant to Mitigate Aquatic Macrophyte Growths at Ibadan, Nigeria,” International Journal of Applied Science and Technology, 4(3), pp. 117-124, 2014.

[4] APHA, “Standard Methods for the Examination of Water and Wastewater,” 20th ed. American Public Health Association/American Water Works Association/Water Environment Federation, Washington, DC, USA, 1998.

[5] Aluko, O. O. and Sridhar, M. K. C. “Application of constructed wetlands to the treatment of leachates from a municipal solid waste landfill in Ibadan, Nigeria,” Journal of Environmental Health, USA, 67 (10), pp. 58-62, 2005.

[6] Anning, A. K., Korsah, P. E. and Ado-Fordjour, P. “Phytoremediation of Wastewater with Limnocharis flava, Thalia geniculata and Typha latifolia in Constructed Wetlands,” International Journal of Phytoremediation, 15(5), pp. 452-464, 2013.

[7] Aondoakaa, S. C. “Effects of Climate Change on Agricultural Productivity in the Federal Capital Territory (FCT), Abuja,” Ethiopian Journal of Environmental Studies and Management (EJESM), 5(4), pp. 559-566, 2012.

[8] Badejo A. A., Coker A. O, and Sridhar M. K. C. “Treatment of tertiary hospital wastewater in a pilot-scale natural treatment system (Reedbed technology),” Research Journal in Engineering and Applied Sciences, 1(5), pp. 274-277, 2012.

[9] Baskar, G., Deeptha, V. T., and Annadurai, R. “Comparison of Treatment Performance between Constructed Wetlands with Different Plants,” International Journal of Research in Engineering and Technology, 3(4), pp. 210-214, 2014.

[10] Calheiros, C. S. C., Rangel, A. O. S. S., and Castro, P. M. L. "Constructed wetland systems vegetated with different plants applied to the treatment of tannery wastewater," Water Research, 41, pp. 1790-1798. 2007.

[11] Debing, J., Lianbi, Z., Xiao song, Y., Jianming, H., Mengbin, Z. and Yuzhong, W. "COD, TN and TP Removal of Typha Wetland Vegetation of Different Structures," Journal of Environmental Studies, 18(2), pp. 183-190, 2009.

[12] Dushenkov, V., Kumar, P., Motto, H., and Raskin, I. "Rhizofiltration: the use of plants to remove heavy metals from aqueous streams," Environ, Sci. Tech., 29(5), pp. 1239- 1245, 1995.

[13] Garbisu, C., Hernadez-Allica, J., Barrutia, O., Alkorta, I. and Becerril, J. M. "Phytoremediation: A technology using green plants to remove contaminants from polluted area," Rev. Environ. Health. 17, pp. 75-90, 2002.

[14] Gupta, P., Roy, S. and Mahindrakar, A. B. "Treatment of Water Using Water Hyacinth, Water Lettuce and Vetiver Grass - A Review," Resources and Environment, 2(5), pp. 202-215, 2012.

[15] Hegazy, A. K., Abdel-Ghani, N. T. and El-Chaghaby, G. A. "Phytoremediation of industrial wastewater potentiality by Typha domingensis," Intl. Journal of Environ. Sci. Tech., 8(3), 639-648, 2011.

[16] Hossien, R. and Mohsen, S. "Performance Removal Nitrate and Phospahte from Treated Municipal Wastewater Using Phragmites australis and Typha latifolia Aquatic Plants," Journal of Civil Engineering and Urbanism, 4(3), pp. 315-321, 2014.

[17] Mahmood, Q., Zheng, P., Islam, E., Hayat, Y., Hassan, M. J., Jilani, G. and Jin, R. C. "Lab Scale Studies on Water Hyacinth (Eichhornia crassipes Marts Solms) for Bio-treatment of Textile Wastewater," Caspian Journal of Env. Sci. 3(2), pp. 83-88, 2005.

[18] Medugu, N. I. "Overview of FCT, Abuja and its Planning Concept," NasiruIdrisMedugu's Blog.htm. 2009, Accessed 26th April, 2014.

[19] Nouri, J., Lorestani, B., Yousefi, N., Khorasani, N., Hasani, A. H., Seif, S. and Cheraghi, M. "Phytoremediation potential of native plants grown in the vicinity of Ahangaran lead-zinc mine (Hamedan, Iran)," Environ. Earth Sci., 62(3), 639-644, 2011.

[20] Lu, Q. "Evaluation of aquatic plants for phytoremediation of eutrophic storm waters," Ph.D Thesis report, University of Florida, Florida, 2009.

[21] Oluwadamisi, E. A. "Evaluation of Wastewater Management Systems in Abuja for Sustainability and Development of Appropriate Engineering Strategy," Masters of Philosophy report, Department of Civil Engineering, University of Ibadan, Nigeria, 2013.

[22] Omenka, E. "Improvement of Decentralized Wastewater Treatment in Asaba," Nigeria. Master's Thesis report, Department of Chemical Engineering, Water and Environmental Engineering, Leed University, Sweden, 2010.

[23] Scholz, M., Xu, J. "Comparison of constructed reed beds with different filter media and macrophytes treating urban stream water contaminated with lead and copper," Ecol. Eng. 18 (3) pp. 385–390, 2002.

[24] Stefani, G. D., Tocchetto, D., Salvato, M. and Borin, M. "Performance of a floating treatment wetland for in-stream water amelioration in NE Italy," Hydrobiologia, 674, pp. 157-167, 2011.

[25] Singh, O. V., Labana, S., Pandey, G., Budhiraja, R., Jain, R. K. "Phytoremediation: An overview of metallic ion decontamination from soil," Appl. Microbiol. Biotechnology, 61, pp. 405-412, 2003.

[26] Srivastava, J., Kalra, S. J. S., and Naraian, R. "Environmental perspectives of Phragmites autralis (Cav.) Trin. Ex. Steudel," Applied Water Science, 4, pp. 193-202, 2004.

[27] Todorovics, C., Garay, M. T., and Bratek, Z. "The use of the reed (Phragmites australis) in wastewater treatment on constructed wetlands," Proceedings of the 8th Hungarian Congress on Plant Physiology and the 6th Hungarian Conference on Photosynthesis, 49(1-2), pp. 81-83, 2005.

[28] Verma, A., Kumari, M., Dhusia, N. and More, N. "Phytoremediation Potential of Phragmites Karka for Arsenic Contaminated Soil and Water," Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT), 8(1), pp. 84-92, 2014.