The effectiveness of Phytogreen system in phytoremediation and bioremediation process to enhance the quality of domestic wastewater

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Abstract

Human being are pollute the water body by different ways. Domestic wastewater is one of them. At present the endeavour of the use of aquatic plants to decontaminate wastewater has been attain very much attention. A study was conducted through bioremediation including a phytogreen zone to assess the capability of aquatic plants in constracted ponds for wastewater treatment. Standard methods were used for the analysis. The SPSS version 20 was used to get the mean, standard deviation and Least Significance Difference (LSD). From the study, it was found that by bioremediation process a great portion of studied parameters were removed. Moreover, from the aquatic plants it has been observed a substantial removals of pollutants. As, the phytoremediation is environment friendly, it could be used in the wastewater management of the nation.

Keywords: Bioremediation, wastewater, aquatic plants, contaminants, lepironia articulata, water hyacinth

Introduction

Currently, wastewater treatments and disposal is a great problem throughout the world. The wastewater treatment processes which are used around the world highly expensive and time consuming. Therefore, the alternative techniques are required. Chemical treatments have many adverse and long term effects on environments. Chemical treatments are polluting various components of environment such as water, air, soil and sediments. Bioremediation is initiated to preserve the environment from the contamination. Bioremediation is one of the effective methods in wastewater cleaning. To clean domestic wastewater through bioremediation, waste stabilization ponds techniques are regarded as the best techniques (Rahman *et al*. 2012). So the environmental friendly procedures are necessary to counteract the environmental pollution. It is reported that for the decontamination of pollutants, bioremediation proved cost effective among all wastewater treatments methods. Domestic wastewater treatments by bioremediation have potentials to reduce lethal contaminants. Aquatic plants can reduce the pollutants from domestic wastewater (Mangunwardoyo *et al*. 2013). Now days, phytoremediation is being used in environmental cleansing and wastewater treatment. It is the latest environment friendly technology to decontaminate pollutants by the phyto extraction (Ziarati, 2014). The aquatic plants such as water hyacinth (*Eichhornia crassipe*s) and cattails (*Typha latifolia*) are regarded as the best species in phytoremediation of wastewater (Sukumaran, 2013). It revealed that water lettuce and lepironia have capability in wastewater treatment. The objectives of this research are to explore the potentiality of aquatic plants as well as the bioremediation process in wastewater treatments.

Materials and methods

Study area

Study area is located in Taman Anggerik, Johor Bahru, Malaysia. It is 35 km from Johor Bahru town and 30 km from Senai International Airport,Johor Bahru. It is a low lying area. It was conducted by two oxidation ponds of Taman Anggerik, Johor Bahru, Malaysia. One facultative pond and another is maturation pond.

Site selection and sampling

On the basis of topography, availability of wastewater and plant species site was selected. It also used GPS in site selection. The samplings were done on weekly. There were 15 stations. From each station, three replications were used.

Descriptions of ponds

Bioremediation of the wastewater of this study was done in modified facultative and maturation ponds. Two ponds were constructed in waste stabilization pond (WSP) which are facultative and second one is maturation pond. In facultative pond, the influents are assembled and stabilized. There were two zones such as influent zone and conventional waste stabilization zone. At this pond, domestic and residential wastewaters from all over Taman Anggerik, Johor Bahru, Malaysia were channeled. First pond is 40-50 m long, 45 m width and depth 2 m. The wastewater consists of kitchen, water bath, washing machine and from the residential area. The second pond is 60-55 m long, 45 m width and depth 1.5 m. The maturation pond (2nd pond) is divided into five zone: modified waste stabilization zone, phytogreen zone, aeration zone, inclined clarification zone and effluent zone. The wastewaters from the first pond were passed to second pond then travel through the modified waste stabilization zone, phytogreen zone, aeration zone and at last reach clarification zone.

Bioremediation activities in different zones of the maturation pond:

In the research, the bioremediation activities were conducted in seven zones.

Influent zone (IZ): there are two channels by which the wastewater entered into this zone.

Conventional wastewater stabilization zone (CSZ):

It is also called facultative zone. In this zone, wastewater settled and three types of bacteria worked. The coarse and large size wastes settled here. In the surface, aerobic, in middle anaerobic and in bottom facultative bacteria worked. In this zone, two-thirds of waste and one- thirds are water.

Modified waste stabilization zone (MSZ):

The smaller size wastes assembled here. In the entry point of this zone, there are a drainage system which filters the larger size particles and wastes. Moreover, sunlight penetration, settling of wastes and the microbial activity occurred in this zone.

Phytogreen zone (PZ)

In this zone aquatic plants were planted on floating platforms. Four plants were selected for it which were cattails, Lepironia articulate, water hyacinth and water lettuce. It is divided into two parts. The first part contains 2 sub Zones and 8 beds. Among them Zone-A are planted by Cattails and Lepironia articulata and the Zone-B by Water lettuce and Water hyacinth. Holders were used for the plants of Zone-A, to stand the plants. The plants of zone B were kept inside net.

Aeration Zone (AZ)

In this zone, two aerated lagoons were used. In order to increase the dissolved oxygen, the lagoons were worked. The wastewater come from Phytogreen zone were rotated here and then passed to clarification zone.

Inclined Clarification Zone (ICZ)

It was made off concrete. The clarifiers that are chosen for this wastewater treatment plant are designed to improve the quality of the water that is being discharged out. The main function of a clarifier is to trap suspended solid and most of the clarifier used in other wastewater treatment plant are flat plate clarifier. However, in this particular wastewater treatment plant, the plate clarifier are inclined about 45 degree. 300 plates were used in clarification zone. This is done to improve the capability of the clarifier to trap more suspended solid using the rule of gravity. Here, the principle of phenomenon was sharing force. Besides that, the plates are arranged in a zigzags manner to improve the amount of contaminant trapped. From here, the trapped particles are transported in the facultative ponds.

Effluents Zone (EZ)

It is the last zone. From this zone the treated wastewater were collected.

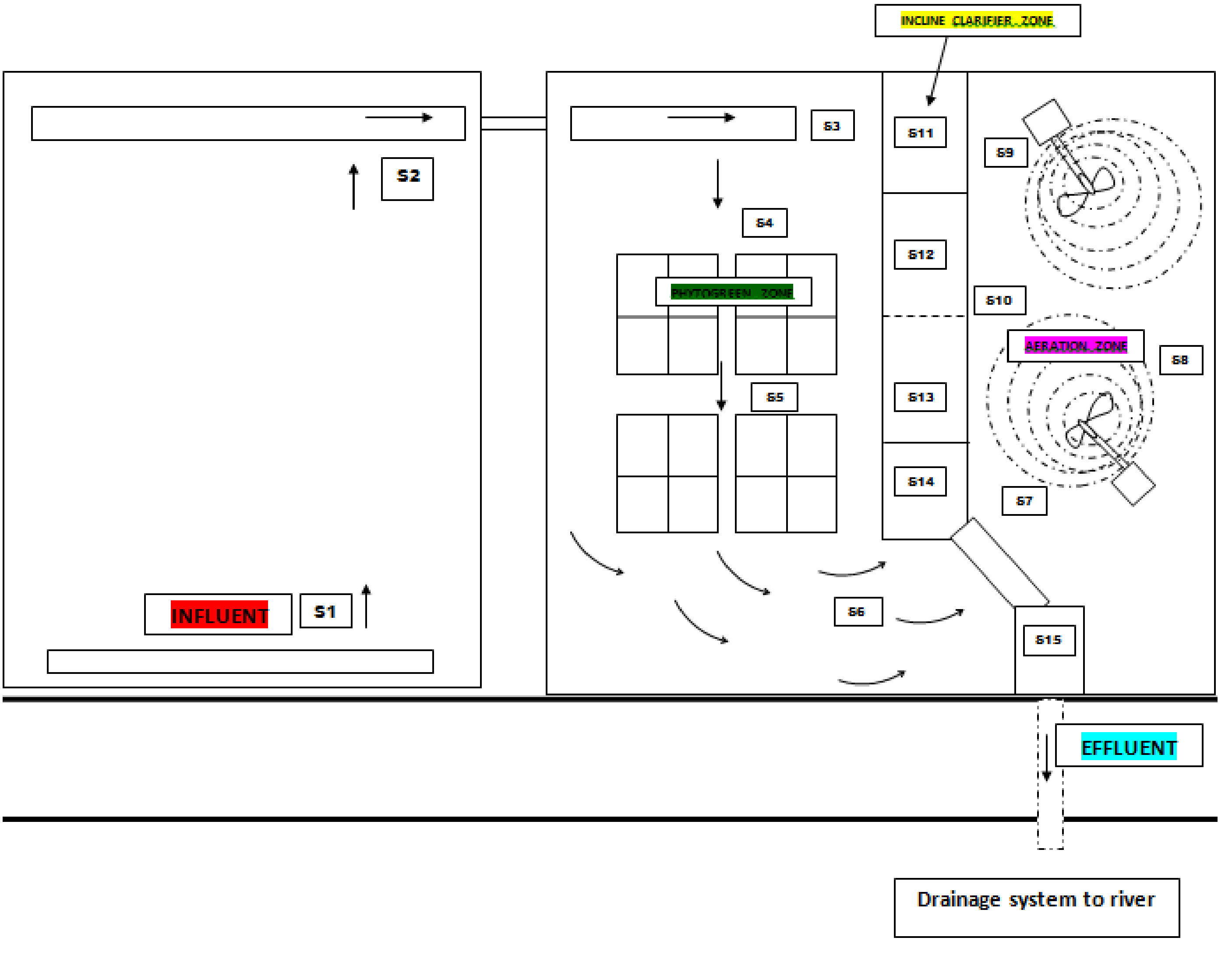

Figure 1: Flow Chart of the Bioremediation process

In situ analysis: The parameters like temperature, pH and turbidity were determined in field using YSI.

Laboratory analysis:

The TSS was measured by gravemetric methods. Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), oil and grease (O&G), ammoniacal nitrogen (NH_3N), nitrate, nitrite, phosphate and potassium were analysed by standard methods.

Statistical analysis:

Least Significance Difference (LSD), standard deviation and mean were calculated by using SPSS software version 20.

Results and discussions

The results and discussions were divided in two parts, in first part temperature, pH, oil and grease BOD, COD, TSS and turbidity. In second part, non-metals likely ammoniacal nitrogen, nitrate, nitrite, phosphate and potassium were discussed.

Change of physico-chemical parameters of different zone in 2014 in the studied wastewater

Temperature

The average temperatures were found 29.98, 29.88, 29.69, 29.45, 29.32, 29.47 and 29.53 º C for influent, conventional waste stabilization, modified waste stabilization, phytogreen, aeration, clarification and effluent zone respectively. The highest average temperature was recorded at influent zone while the lowest temperature was measured at aeration zone. The temperatures were observed lower after treatments probably due to absorption of heat by phytogreen zone. From the temperature data, it is concluded that there were not great differences among the temperatures of different zones. The similar opinions were made by Reddy et al. (1983).

pH

It has been found from Figure 2 that the average pH was 8.35 at influent zone, 8.17 at conventional waste stabilization zone, 7.99 at modified waste stabilization zone, 7.76 at phytogreen zone, 7.58 at aeration, 7.68 at clarification zone and 7.50 at effluents zone. The higher pH was determined at influent zone and waste stabilization. The results were supported by (Basavaling and Stanley, 1995) whereas the lower pH was detected from effluent zone. The pH level was decreased in phytogreen. Dipu et al. (2011) found neutral pH from alkaline pH by the experiment of water lettuce. It was found significance differences consecutively from one zone to another zone.

Oil and grease

The average concentrations of oil and grease were 32.10, 28.92, 25.75, 11.65, 8.32, 5.24 and 4.03 mg/L at influent, conventional waste stabilization, modified waste stabilization, phytogreen, aeration, clarification and effluent zone respectively. It was found that gradually the oil and grease concentrations diminished but it decreased dramatically in phytogreen zone (Figure 2). Xia et al. (2003) found Lepironia can reduce oil from wastewater. It was observed from the study of Dune et al. (2013) that water hyacinth can reduce oil and grease from the wastewater. A significance difference was observed among the oil and grease values in different zones.

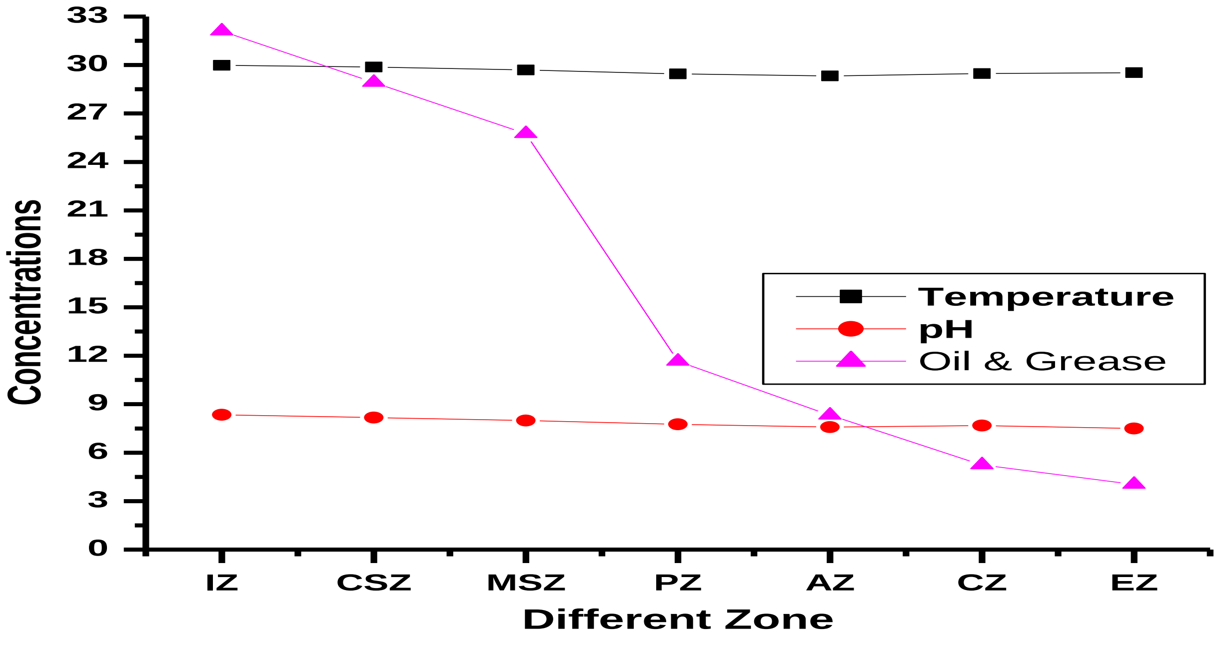

Figure 2: Concentrations of temperature, pH and oil and grease in different zone in bioremediation process

BOD_5

Recorded average BOD level were 355.42, 315.37, 69.09, 26.23, 16.71, 9.64 and 6.02 mg/L at influent, conventional waste stabilization, modified waste stabilization, phytogreen, aeration, clarification and effluent zone respectively. It was observed that the BOD level reduced slowly from influent zone to upto conventional waste stabilization zone. Then the BOD level decreased drastically in modified stabilized zone and again little bit slowly in phytogreen zone (Figure 3). Possibly due to the drainage the solids filter and settling of wastes as well as the bacterial activity decreased BOD reduced in modified stabilization zone. The opinions are supported by Al-Hashimi and Hussain (2013). Probably owing to the adsorption and uptake of wastes were made by plants in phytogreen zone. Calheiros et al. (2008) conducted an experiment on wastewater treatment by cattails and recorded higher BOD reduction. Kouki et al. (2012) found that 76 % BOD was reduced by cattails from phyto-treatment of wastewater. Gamage and Yapa (2001) used water hyacinth in the treatment of textile mill wastewater and reported 75 % BOD removal. However, Kulatillake and Yapa (1984) found 99 % BOD reduction for rubber factory effluents. Awuah et al. (2004) found by using water lettuce that it can reduced 93 % BOD. There were significance differences among the BOD values of all zones.

COD

Average COD values were 699.73 mg/L for influent zone, 622.66 mg/L for conventional waste stabilization zone, 207.26 mg/L for modified waste stabilization zone, 78.25 mg/L for phytogreen zone, 45.90 mg/ L aeration zone, 25.98 mg/L for clarification zone and 17.82 mg/L for effluent zone. It has been observed that the COD content were higher in influent zone and it reduced a lot at modified stabilization zone followed by phytogreen zone (Figure 3). Because of drainage, the large sizes solids are screened and reduced COD level. The agreement is supported by Al-Hashimi and Hussain (2013). Calheiros et al. (2008) worked on wastewater treatment with cattails and recorded higher COD reduction. It revealed that the chemical oxygen demand 82 % removed by cattails from phyto-treatment of wastewater (Kouki et al., 2012). Gamage and Yapa (2001) used water hyacinth in the treatment of wastewater and reported COD reductions were 81.4 % respectively. However, Kulatillake and Yapa (1984) found 80% COD reduction from their experiment. It was observed 59 % COD reduction by the experiment of Awuah et al. (2004). It was found significance difference among COD values at different zones.

TSS

TSS concentrations were found 266.18, 238.08, 115.81, 252.13, 53.88, 41.44, 32.44 and 26.81 mg/L at influent, conventional waste stabilization, modified waste stabilization, phytogreen, aeration, clarification and effluent zone respectively. The TSS content decreased significantly at modified stabilization and phytogreen zone (Figure 3). Due to the settling in modified stabilization zone TSS content decreased. The total suspended solids removed 96 % by cattails from phyto-treatment of wastewater (Kouki et al., 2012). A significance difference was observed in TSS values in all 7 zones.

Turbidity

The average turbidity contents were 774.54, 749.04, 684.04, 167.26, 121.66, 20.72 and 14.70 NTU for influent, conventional waste stabilization, modified waste stabilization, phytogreen, aeration, clarification and effluent zone respectively. It has been found that turbidity levels were reduced drastically in phytogreen zone (Figure 3). Turbidity can be reduced by aquatic plants (Mangunwardoyo et al., 2013). It has been found significance difference in turbidity values in different zones.

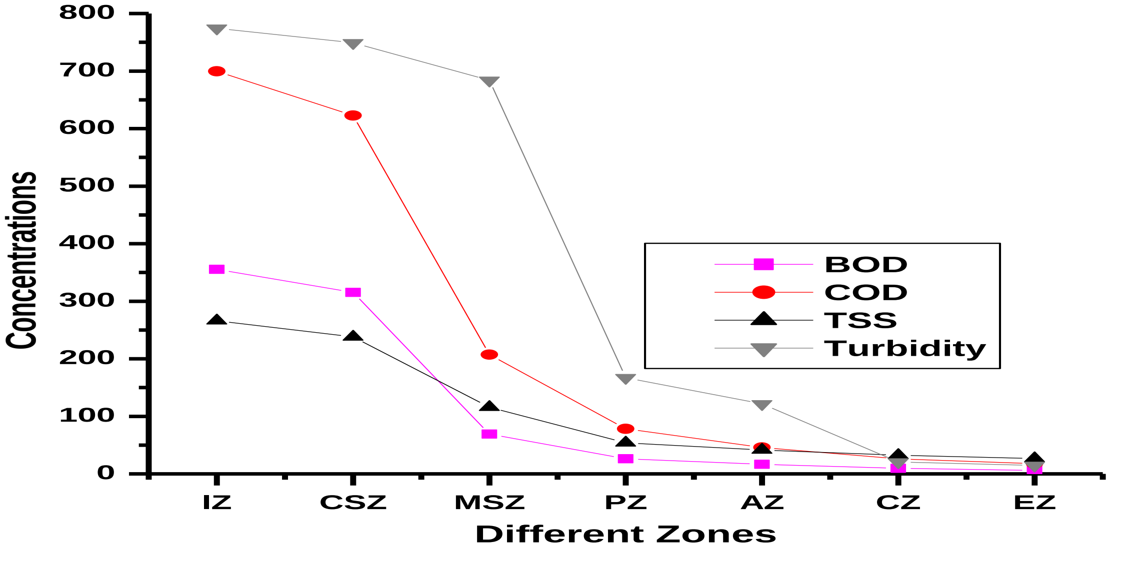

Figure 3: Concentrations of BOD, COD, TSS and turbidity in different zones in bioremediation process

Status of non- metals in different zone of the year 2014 in the studied wastewater

Ammoniacal nitrogen

The average concentrations of ammoniacal nitrogen were detected 60.38, 55.46, 21.18, 15.24, 13.84, 11.87 and 7.76 mg/L for influent, conventional waste stabilization, modified waste stabilization, phytogreen, aeration, clarification and effluent zone respectively (Figure 3). The highest ammonia was recorded in influent and conventional zone. Ammonia accumulates in primary stabilization ponds (Basavaling and Stanley, 1995). A dramatic decrease of ammonia was observed in modified stabilization zone (Figure 3). Because of filter the larger solids filtered and decreased the ammoniacal nitrogen in modified stabilized zone. Awuah et al. (2004) used water lettuce in wastewater treatment and found that it can remove 95 % ammoniacal nitrogen. A significance difference was observed in various zones.

Nitrate

The average nitrate concentrations were 16.82 mg/L at influent 15.60 mg/L at conventional waste stabilization zone, 14.39 mg/L at modified waste stabilization zone, 12.87 mg/L at phytogreen zone, 10.15 mg/L at aeration zone, 7.54 mg/L at clarification zone and 7.17 mg/L effluent zone (Figure 3). It was observed a comparatively higher decrease of nitrate in phytogreen zone (Figure 3). Awuah et al. (2004) conducted a study with wastewater treatment by water lettuce and observed it could remove 70 %. It was reported from the study of Ingersoll and Baker (1998) that water lettuce can removed nitrate 31 to 51 %. A significant difference has been found in nitrate content among all zones.

Nitrite

The average nitrite content were 0.15, 0.12, 0.12, 0.11, 0.06, 0.05 and 0.05 mg/L for influent, conventional waste stabilization, modified waste stabilization, phytogreen, aeration, clarification and effluent zone respectively (Figure 3). It has been found that the nitrite reduction was found more in aeration zone (Figure 3). In the aeration zone, the oxygen incorporation was happened which increased bacterial activity and reduced the nitrite concentrations. The opinion is supported by Kumar et al. (2013). There are significance differences of nitrite content of different zones except between conventional and modified waste stabilization zones.

Phosphate

The average phosphate concentrations were 13.69 for influent, 12.51 for conventional waste stabilization, 11.32 mg/L for modified waste stabilization, 9.48 mg/L for phytogreen, 6.87 mg/L for aeration, 4.57 mg/L for clarification and 4.20 mg/L for effluent zone (Figure 3). In the phytogreen zone, comparatively higher phosphate reduction done (Figure 3). The similar results were recorded by Awuah et al. (2004). It was found significance difference of phosphate concentrations among all zones

Potassium

The average potassium content were 1.75, 1.57, 1.39, 1.09, 0.79, 0.63 and 0.37 mg/L at for influent, conventional waste stabilization, modified waste stabilization, phytogreen, aeration, clarification and effluent zone respectively (Figure 3). In phytogreen zone the potassium concentrations were reduced because aquatic plants like water hyacinth can uptake high potassium. The observation is in agreement with Reddy et al (1990). A significance difference was observed in potassium content in all zones.

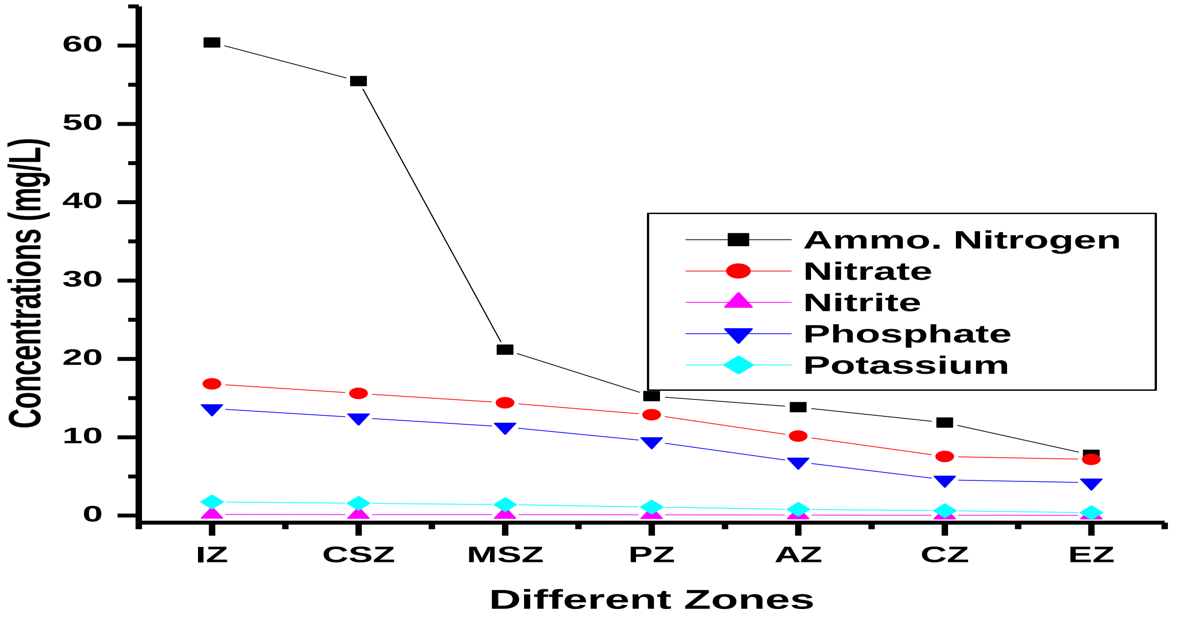

Figure 4: Concentrations of ammoniacal nitrogen, nitrate, nitrite, phosphate and potassium in different zone of bioremediation process

Conclusions

The studied results revealed that temperature were not varied significantly in different zones. pH gradually decrease and reach near neutral by the end of the treatment. Oil and grease concentration decreased mostly in phytogreen while BOD, COD, TSS, turbidity and ammoniacal nitrogen decreased highly in modified stabilization zone followed by phytogreen zone. Furthermore, nitrate, nitrite, phosphate and potassium concentrations were decreased slowly from influent zone to upto effluent zone but in aeration zone it was reduced comparatively better. So, the role of aquatic plants are enormous in decontamination of pollutants.

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