CHAPTER 6

MANAGEMENT OF WATER POLLUTION THROUGH PHYTOREMEDIATION

6.1 Introduction

For the overall development of a country, industries play a crucial role. In this context core industries such as coal mining have a pivotal part in rapid urbanization of the country. Due to this expeditious expansion of industrial activities, global degradation of the environment is also taking place. Water pollution is one of the major concerns in this milieu. Discharging of industrial waste water, domestic and agricultural water directly into the reservoir is deteriorating the water quality of the area. India is the second largest producer of coal in the world. Northern Coal field Limited produces about 14% of the total coal production in India. This opencast coal mining activity causes various environmental problems including water pollution. Exposure to these pollutants may cause severe issues to health if exposed for a considerable period of time. Since, there is limited amount of water present for human consumption to fulfil their day to day needs. However, this finite quantity of water gets polluted due to continuous pouring of pollutants through industries & other anthropogenic activities. The release of toxic effluents from different industries such as steel, textile, metal, tanneries, oil refineries, mines, electroplating, fertilizers, soaps, detergent, paper, leather, sugar etc. add harmful organic chemicals, oils, heavy metals, dyes, fluoride ,chlorides, phenols, pesticides, insecticides, soaps & detergents into water bodies & causes water pollution (hanchang2009). The effluents discharge from these industries can be both carcinogenic & mutagenic in nature. Therefore, remediation of it becomes important.

Since, many of the technological measures employed for the removal of pollutants are expensive & deleterious to human health. Several conventional treatment methods such as flocculation, coagulation, membrane filtration, precipitation, nanofiltration, electrocoagulation, floatation, ion exchange, adsorption etc. These remedial measures have their own disadvantages such as production of toxic sludge, incomplete removal of

industrial pollutants, requirement of high energy, pre-requisite of high amount of capitals etc. Hence, these treatment methods are not providing viable initiatives as the pollutants are simply getting conveyed from wastewater to sludge thereby posing an issue of disposal at the site of waste treatment and management. Also these conventional treatment methods incurred high cost on the economy of the country. Therefore for developing countries' economies like India managing such high cost of treatment becomes difficult due to their other priorities for investment in the sectors like health, education etc. To achieve solutions to such problems which are sustainable as well as economical in nature, Phytoremediation can be considered as the best cost effective & eco-friendly method for the wastewater remediation. Phytoremediation can be defined as the use of plants to remove pollutants from the environment or to render them harmless (Salt et al 1998). Five main subgroup of Phytoremediation have been identified:

1) Phytoextraction: This technique involves the use of plants for removal of metals from the soil & concentrate them in the harvestable parts of plants (Kumar et al 1995).
2) Phytodegradation: This involves plants & associated microbes for degradation of organic pollutants (Burken et al 1997).
3) Phytostabilization: It involves plants to reduce the mobility & bioavailability of pollutants in the environment either by immobilisation or by prevention of migration (Vangronsveld et al 1995; Smith et al 1972).
4) Phytovolatilisation: It is defined as the volatilisation of pollutants into the atmosphere via plants (Burken et al 1999; Banuelos et al 1997).
5) Rhizofiltration: It includes absorption of metals from streams through plants roots (Dushenkov et al 1995).

Hence, immediate implication of Phytoremediation technique at the site of industrial units helps in making it more laudable & worthwhile technique over the other plethoric technique present for the remediation of waste generated through these industries. Several Italian species of aquatic macrophytes such as water hyacinth (*Eichhornia* sp.) duckweeds (*Lemna* sp., *Spirodella* sp.) Water thyme (*Hydrilla* sp.) water moss (*Salvinia* sp.) guppy grass (*Najas* sp.) pond weed (*Potamogeton* sp.) water lettuce (*Pistia* sp.) have been used in the earlier studies by researchers to monitor the effect of these species for the removal of pollutants through Phytoremediation. Hence in this study we have utilized water hyacinth (*Eichhornia* sp.) and a wetland species known as *phragmites australis* for the removal of contaminants at one of the monitoring stations discharging their effluents directly into the reservoir thereby posing an adverse impact on the water quality of the reservoir. In Phytoremediation remediation non edible plants are favoured over the edible for Phytoremediation process so that toxic elements can be prohibited from entering into the food chain by the process of biomagnification. Thus, the use of these aquatic plant species for Phytoremediation could be more suitable due to their aquatic habitat as well as stress tolerance capacity. Apart from these features it is more accessible, efficient, cost effective & eco-friendly nature.

Water hyacinth (*Eichhornia crassipes*) is a free floating, perennial aquatic plant belonging to family Pontederiaceae, which mostly hegemonizes the fresh water system of low impetus. Being one of the most noxious invader of aquatic environment, it possess huge problem to this habitat. The plant is indigenous to Brazil & later on it was invaded to various part of the world during the late 1800s (Vane Driesche et al 2002). The invasive weed has spread quickly from Amazon to many tropical and subtropical countries of the Latin America, the Caribbean, Africa, Southeast Asia and the Pacific (Julien 2001; Navarro & Phiri 2000). In India, it appeared at the beginning of 1890 and spread to all parts of the country (Tellez et al 2008). This incursive weed creates serious

environmental & socio economic problems by hindering the growth of other aquatic flora & faunal community as well as it act as a limiting factor by affecting the hydropower generation, irrigation, transportation and accelerating the increase in the number of pathogens. Water hyacinth is one of the fastest growing macrophytes in the world (Wolverton &McDonald 1979) & it can exceedingly alter the ecosystems in which it invades (Penfound & Earle 1948). It reproduces exceedingly rapidly by producing daughter plants on stolons, 10 plants can produce a mat of 650000 plants in one growing reason (Penfound & Earle 1948). This quick growth of this weeds causes serious impact on water quality of the aquatic habitat. Though the weed is obnoxious to the aquatic environment in general but here in this study it acts as a boon due to its high biomass production rate, high tolerance to pollution & its heavy metal and nutrient absorption capacities (Chanakya et al 1993; Singhal & Rai 2003; Swarnlatha et al 2015) making it suitable for contaminated water treatment. Also due to its exorbitant protein content & ample availability in tropical and subtropical countries like India, a large number of scientific research has been conveyed to know the efficiency of this invasive weed in wastewater treatment.

Under the present research, the removal of various contaminants through water hyacinth accompanied with *Phragmites australis* from effluent through coal mine was evaluated. Here, Total Suspended Solids (TSS), Total Dissolved Solids (TDS) along with other cations anions and heavy metals which were reported in excess and were processed in waste water through these two plants. These pollutants cause severe damage to plant growth, its metabolism, change in enzymatic activities and biosynthesis due to its long residence time in surface water thereby used for cultivation of crops. Excessive accumulation of these contaminants are toxic to the plants since it causes severe alteration in physiological & biochemical processes. The main objective of this experiment is to evaluate the efficiency of water hyacinth along with *Phragmites australis* to remove the

various contaminants present in the surface water released through one of the major source of industrial effluent directly into the reservoir. This cost effective measure can be even used in area without any high cost incursion on economy as well as without having any high expenditures on chemical treatment through conventional method.

6.2 Material and Methods

In this study, two types of species such as water hyacinth (*Eichhornia crassipes*) and common reed (*Phragmites australis*) were used which served as an instrument of Phytoremediation. These aquatic weeds were used for the reduction of the amount of TSS, TDS, Cations, Anions & heavy metals from the contaminated untreated mine wastewater from Balia Nala. These aquatic weeds were collected from the local area of Varanasi, India. After collection they were properly rinsed with tap water in order to eliminate any type of foreign material such as dust, insect larvae & epiphytes etc. present on them. Then the plants were placed in a rectangular glass box with tap water without addition of any nutrient solution under natural sunlight for a period of 15 days. This is done in order to remove any kind of dissolved impurities present in the roots, stems and leaves of the plants and also to adapt to the new environment. Lastly, the plants of approximately same sizes were selected to perform the experiments. The analysis of wastewater from Balia Nala was carried out for estimation of physicochemical parameters before and after the experiments.

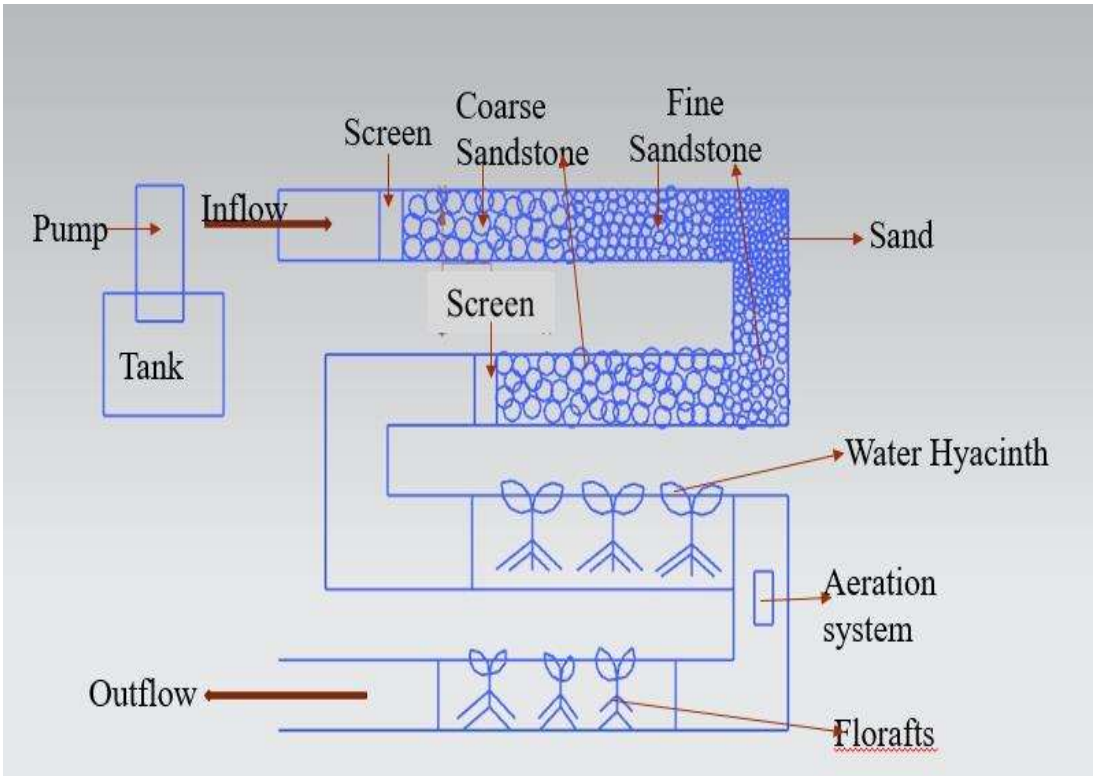

Fig 6.1 Line Diagram representing Experimental Setup

Fig 6.2 Experimental Setup for Mitigation at Department Laboratory

The experimental unit was employed in the tinkering Lab of the Department of Mining Engineering at IIT (BHU), Varanasi. It consists of an 18 m long rectangular channel (as shown in fig. 6.1 and 6.2). The channel was filled with effluent water collected from Balia Nala at an ambient temperature of about 25-30^{0}C. After this 100 ml of water sample was collected from it at 0 day. From this sample various parameters were evaluated at Mining Department Laboratory as well as CIFC laboratory & through ICP at ISLS and this reading was regarded as initial reading for the experiment without any treatment process i.e. Phytoremediation 10.4% of the total length of channel is the amount of plant length (water hyacinth) i.e. 1.87 m of plant length was used for the experiment in the channel for treatment of effluent discharged from Balia Nala. While 18% of the length of the channel is the length of the Phytorid i.e. *Phragmites australis* of approximately 1.29m length was utilized. A dimension of 2m x 1m x 1m of cuboid of constructed wetlands with fibreglass was employed in the channel for treatment of industrial effluents. About 1m of length of the channel was used for the construction of the filtration system made up of different sizes of sandstone starting from coarse sandstone of 22.4mm diameter to fine sandstone of 11.2mm diameter followed by fine grain sand. After this again the fine grained sandstone is followed by fine sand stone to coarse grained sandstone with a screen of fine mesh size at the starting & end of the filtration system. This filtration system was employed after the 1m of length at the point of inflow of the effluents into the channel. Apart from this an aeration system was placed between the two wetland species in order to provide adequate amounts of oxygen to both the species for proper functioning during the experiments. The test duration was for 15 days i.e. 15th day reading was treated as the final reading to observe the change in concentration of the toxic parameters during a time span of 15 days. Deionised water was added continuously in order to compensate the water Ions through plant transpiration or evaporation. The changes in various parameters were monitored at regular intervals; one litre of effluent water collected from Balia Nala

was kept in a beaker without using any of the components of the experiment. This effluent water was used as a control. After each experiment, the plants were recycled for the next experiment & therefore after a number of recycling the plants were harvested. When the overall lifecycle of the plants was completed, they were burnt to produce bioenergy, a type of renewable energy which acts as a manure to the soil for cultivation thereby making the nutrients to release directly into the soil for enhancing the productivity of the soil.

S. No.	Parameters (units)	Initial Conc. (0 Day)	Final Conc. (15 Days)	Permissible Limit by WHO/BIS
1)	pH	7.2	6.9	6.5-8.5
2)	EC (µS/cm)	1056	928	1000
3)	TDS (mg/L)	528	464	500
4)	TSS (mg/L)	697	356	500
5)	Magnesium (mg/L)	32	24	50
6)	Calcium (mg/L)	79	70	75
7)	Nitrate (mg/L)	68	50	45
8)	Sulphate (mg/L)	329	283	150
9)	Zinc (mg/L)	5.76	4.12	5
10)	Nickel (mg/L)	0.29	0.15	0.2
11)	Chromium (mg/L)	0.06	0.01	0.01
12)	Cadmium (mg/L)	0.26	0.17	0.1

Table 6.1 Result of Experimental Setup for treatment of Mine Waste Water

6.3 Results and Discussion

Studies related to Phytoremediation can be seen as a function of relative plant growth accumulation and the subsequent reduction in the water toxicity by the plants employed in the process (Saha et al 2017). The technique used in this study can be more

appropriately called rhizofiltration (Dushenkov et al 1995) which is also a type of phytoremediation as discussed earlier in this chapter. The analysis of the effluent water from Balia Nala before and after the implementation of the phytoremediation was done. The initial and final reading of the experiment during 15 days is shown in Table 6.1. The determination of pH, electrical conductivity, total dissolved solids, total suspended solids, magnesium, calcium, nitrate, sulphate, zinc, nickel, chromium & cadmium was done after 15 days of phytoremediation. The analysis of pH, electrical conductivity, total dissolved solid & total suspended solid were done using Hanna Hi 9868 Multiparameter analyser and magnesium, calcium, nitrate, and sulphate were analysed by ion chromatography. Similarly, the values of zinc, nickel, chromium & cadmium were recorded using ICP-AES before and after the experiment. These parameters in the wastewater effluent from Balia Nala of the Singrauli region were measured to assess the toxins removal potential of wetland plant species Water Hyacinth and Common Reed. The result indicated that the experimental setup used in the study was very efficient in reducing the concentration of various parameters listed in Table 6.3.

After collection of effluent from Balia Nala of Singrauli Coalfield, the pH was estimated as 7.2. The result after the treatment through phytoremediation was found to be 6.9 thereby showing a decrease of 3.5% from its initial value in 15 days. However, there was no change in pH in the case of control experiment during this period. It can be inferred from the experiment that the reduction in pH might be due to the absorption of pollutants by the plants (Saha et al 2017).

Similarly, the analysis of electrical conductivity, total dissolved solids and total suspended solids was conducted after the collection of effluent from Balia Nala. The initial concentration of electrical conductivity, total dissolved solids and total suspended solids was found to be 1056 μS/cm, 528 mg/L, and 697 mg/L respectively. During the experiment, it was observed that electrical conductivity, total dissolved solids and total

suspended solids of effluent decreased gradually over time due to removal of cations, anions, and heavy metals through the uptake by roots of the wetland species as well as by arresting insoluble sediments and contaminants through the sandstone filtration employed before the wetland species (Mant et al 2007). While no change was observed in the case of control in any of the 3 parameters. The final concentrations were found to be 928 µS/cm, 464 mg/L and 356 mg/L respectively. It can be concluded from the results that the whole experimental setup was very efficient in the removal of T.S.S. thereby acting as an eco-friendly technique for its removal.

Results revealed that the concentration of anions and cations showed a considerable decrease in 15 days. The initial concentrations of magnesium, calcium, nitrate, and sulphate were found to be 32 mg/L, 79 mg/L, 68 mg/L, and 329 mg/L respectively. However, the final concentration was observed to be 24 mg/L, 70 mg/L, 50 mg/L, and 283 mg/L respectively after 15 days of experimental treatment. The concentration of cations and anions decreased due to the absorption of these ions through the roots of the wetland species (Tiwari et al 2007). These wetland species produce bioactive compounds that undergo physicochemical changes in water leading to enhanced absorption by the roots of the plants (Upadhayay et al 2007). On the other hand, no considerable change was observed in the concentration of cations and anions in the control experimental setup. The concentration of heavy metals at day 0 of the experiment was recorded as 5.76 mg/L, 0.29 mg/L, 0.06 mg/L, and 0.26 mg/L for zinc, nickel, chromium and cadmium respectively while the final concentration of these constituents was found to be 4.12 mg/L, 0.15 mg/L, 0.01 mg/L, and 0.17 mg/L respectively. The change in results revealed a considerable decrease in their concentration. The removal of these contaminants in effluent water is attributed to the special characteristic feature of the wetland species water hyacinth & common reed. The expulsion of these heavy metals is attributed to the fibrous and dense root system, broad leaves, and fast growth of these species (Gupta et al

2009). These species can be considered as a good alternative to conventional treatment as these techniques of phytoremediation can bioaccumulate a considerable amount of these metals (Carbonell et al 1998). The hardness of effluent water was also reduced after phytoremediation since there was a considerable decrease in the concentration of magnesium and calcium ions (Saha et al 2017). Therefore, phytoremediation can be considered as an effective tool for the removal of these contaminants using bioaccumulation and bioconcentration which increases with the age of the plants as well as with the external availability of these pollutants in water. It can act as a sustainable and eco-friendly remediation with great potential for improving the aesthetics of the environment.

6.4 Conclusions

The current experimental setup can be considered as a sustainable alternative for the treatment of effluent released through Balia Nala (one of the sampling site considered for the study directly having industrial effluent through the mines of Northern Coalfield Limited and releasing it into Govind Ballabh Pant reservoir) containing various kinds of contaminants. The wetland species used in the experiment were perennial as well as free floating in nature. These wetland species can be installed in any pond, lake or still water system without any acquisition of land to remove pollutants from water. Another feature which makes it more suitable for the treatment is the floating nature of these wetland species which does not cause any threat to the storage volume of the existing water body. Apart from this, the experimental setup used in the study does not involve any complicated technology for its induction. The floating nature of these species also makes them suitable for water bodies with fluctuating water levels. The anatomy of these species plays an important role in removal of these contaminants since the roots of these species helps in the removal of pollutants from effluent water due to its property of direct absorption of nutrients through the roots as well as providing a long residence time for

the development of microbial film and filtration of the waste water. In this study, the sandstone filtration system helps in removal of insoluble coarse contaminants present in the waste water by arresting them through the method of sedimentation and filtration. While the wetland species are effective for reducing the concentration of dissolved nutrients such as magnesium, calcium, chromium, cadmium, etc. The results depicted in Table 6.1 exhibit the performance of the experimental setup used in the study inferring that it was highly efficient in removal of the contaminants for the effluent with an index ranging from 3% to 80% for various constituents after a residence time of 15 days. Beside it, the removal of contaminants through waste water, these wetland species can be used as a biofertilizer after the completion of its life cycle as these remains of the plants in terms of biomass is rich in nitrogen and other essential nutrients for soil regeneration without having any detrimental effect on the environment. Apart from its use as a manure, it can be used for anaerobic digestion for the production of methane which can be used as biogas. These wetland species can also be used for fermentation of sugar into alcohol, compost, etc. Therefore, the above experimental procedure can be helpful in recovering the expenses of the treatment through phytoremediation without posing any detrimental effect on the environment. Hence, the phytoremediation treatment used in the study for cleaning the industrial effluent can be recommended as an efficient and cost effective tool at this time water, energy and environmental crisis in a developing country like India which possess huge impact on the environment by using conventional chemical treatment for the removal of pollutant. The next Chapter exhibits the conclusions drawn from all the chapters in a systematic manner.