# PHYTOREMEDIATION OF TOXIC METALS USING *Alternanthera philoxeroides* (ALLIGATOR WEED) TO CLEAN UP THE CONTAMINATED SITES OF RIVER CHAMBAL, KOTA.

**Zainul Abideen Ansari[1], Pallavi Sharma[2]***
[1]*Career Point University, Kota, India*
[2]*Department of Basic and Applied Sciences, Modi Institute of Management and Technology, Kota, India.*

**ABSTRACT**

The periodic physicochemical parameters and heavy metals (Cd, Cr, Zn, Pb) of wastewater collected from three contaminated sites (Raipura, Sazidehra and Akelgarh) of river Chambal were investigated periodically. These physiochemical parameters were analyzed by standard methods. The pH of the wastewater and soil was found to be alkaline and temperature varied from 23-34 ºC. The Raipura site was found to be more contaminated. The maximum total dissolved solid was 1613, the maximum biological oxygen demand was 2.6 mg/l and the maximum chemical oxygen demand was 91.50mg/l at Raipura sites. The maximum DO was found to be at Sazidhera sites (705mg/l). The EC content was found to be maximum at Raipura sites and the OC was found to be high at Sazidehra sites. The physicochemical parameters studied were higher compared with the permissible limit prescribed by the United States Environmental Protection Agency and World Health Organization. Some remedial steps to be taken for avoiding water pollution. Phytoremediation is promising technology for heavy metals is environmentally friendly and cost effective the biochemical parameters (protein,chlorophyll,proline) were higher in plants at Sazidehra sites. The maximum concentration of heavy metals was at Raipura sites (Pb,Cd,Cr,Zn).In the present study at all the locations studied *Alternanthera philoxeroides* accumulated higher concentrations of heavy metals in the roots and it was found to be in the order of Zn>Pb>Cr>Cd.Maximum values of BCF for Cd were 25.716 indicating that the accumulation potential of Cd by *Alternanthera philoxeroides* is higher. TF reveals that Zn is more mobile from roots to shoots.Based on BCF values *Alternanthera philoxeroide*s can be utilized as a good Phytoaccumulator of Cd, Pb,Cr,Zn.

Keywords: *Alternanthera philoxeroides,* Cadmium, chlorophyll, Chromium, Lead, proline, protein, Zinc

## INTRODUCTION

Rajasthan is the largest state of India, which covers approximately 10.4 % area of the country but receives only 1/100 of the total rains. Therefore, the state faces water crisis every year. Due to arid and semi arid climate and insufficient surface water resources, Rajasthan depends heavily on groundwater for drinking and for agriculture purpose [21].

Some areas of river Chambal are heavily contaminated because of the unplanned industrial growth and accumulation of sewage waste without proper treatment. The river Chambal is the main source of raw water for many industries in Kota such as fertilizers, thermal, glass and chemical industries. The river is currently facing tremendous pressure due to encroachments, discharge of untreated domestic and industrial waste, dumping of solid waste and illegal diversion of water. However, the river remains less examined with regard to important base-line information [18].

Studies have shown that improvements to a drinking water source or increased provision of water can reduce the number of disease-causing pathogens ingested by a community [15]. Now, Water pollution has become a major problem globally and a leading cause of diseases worldwide with approximately 14000 people daily losing life because of water pollution [34], [47].

Environmental contamination through industrial waste is one of the major causes of water pollution. The specific contaminants leading to pollution in water include a range of chemicals (Heavy metals), pathogens, physical and sensory changes like high temperature and discoloration [8],[29],[7],[38],[31].One of the most well documented naturally occurring contaminants are arsenic which affects drinking water supplies in a number of countries [30] and fluoride [16],[3].

Heavy metals get deposited in soil and easily enter the food chain, accumulate in the bodies of animals and human beings and cause threats to human, animals and ecosystem health. If the metals are ingested beyond the permitted concentration, they can cause serious health disorders [4]. Heavy metals are accumulated as high concentrations in water, soil sediments and plants. This poses a challenging problem to the world of science and human kind. Therefore, it is necessary to treat metal-contaminated wastewater prior to its discharge to the environment. Prevailing technologies to remove contamination are efficient but expensive, labour intensive and soil disturbing [32].

Phytoremediation is the use of living green plants for *in situ* risk reduction or removal of various contaminants including heavy metals from contaminated soil, water, sediments and air [12],[10]. Phytoremediation can be classified as extraction, plant tissue concentrations, contaminant degradation, volatilization, immobilization at root level, and finally, erosion level and infiltration control. Extraction processes when used in water-based culture are called Rhizofiltration which is a maturing technology [36].This technology exploits plant's innate biological mechanisms for human welfare.

*Alternanthera philoxeroides (*Alligator weed) is a perennial, stoloniferous herb; widely grown in rivers, lakes, ponds as well as many terrestrial habitats, used for the sorptive removal of heavy metals like Ni(II), Zn(II),Pb and Cr(VI) etc. from waste water aqueous solutions [46].The objectives of this study were to investigate physiochemical parameters and heavy metal contents of contaminated sites of river Chambal and soil and to assess the potential of *Alternanthera philoxeroides* to phytoremediated the soil and water contaminated with heavy metals.

## MATERIALS AND METHODS

**Experimental Site**: Collection of water and soil samples from Sazidehra Nallah, Raipura Nallah and Akelgarh (River Chambal/Control Site). The samples were collected in every three months duration.

### Physiochemical analysis

Selected physicochemical parameters such as pH, temperature, turbidity, Total Dissolved Solids (TDS), Biological Oxygen Demand (BOD), Chemical Oxygen demand (COD) in the water were analyzed according to [1] and [43].The DO parameter was analyzed according to Romanian Standard [41].

### Estimation of Soil Parameters:-

**Electrical conductivity (EC)**: EC was measured according to Chapman [11].

**Organic Carbon (OC)**: OC was measured according to the method of Walkley and Black [45].

**Estimation of Chlorophyll and Carotenoids content**: Chlorophyll ‘a+b’ (total chlorophyll) and total carotenoids were determined by the method of Arnon [2] and Krik and Allen [28] respectively.

**Estimation of Proline content**

Proline concentration was determined using the method of Bates [5]. Fresh leaves (0.125gm) were homogenized in 5 ml of aqueous sulphosalicylic acid (3%). The homogenate was centrifuged at 9000 × g for 15 min. A 2 ml aliquot of the supernatant was mixed with an equal volume of acetic acid and ninhydrin and incubated for 1 h at 100°C. The reaction was terminated on ice bath and extracted with 4 ml of toluene. The extract was vortexed for 20 s and the chromatophore-containing toluene was aspirated from the aqueous phase and absorbance determined photometrically at 520 nm using toluene for a blank.

**Estimation of Protein Content:** Protein content was estimated according to Osborne [33].

**Heavy metals analysis in water, soil and plant samples**

The samples to be analyzed were digested with aqua regia. The digested samples were analyzed for heavy metals (Cd, Pb, Cr and Zn) using atomic absorption spectrophotometer (AAS VGB 210 System). The instrument setting and operational conditions were done in accordance with the manufacturers specifications. Set the lamp current, slit width and wavelength (Cd: 3.5mA,0.5nm,228.8nm; Pb:10mA,1.0nm,217nm, Cr:4mA,0.5nm,357.9nm and Zn:8mA,1.0nm,217nm).Specific cathode lamps were used to analyze the samples. The instrument has minimum detection limit in the flame method using flame gases (Air-Acetylene).

**Bioconcentration Factor and Translocation Ability:**

The bioconcentration factor (BCF) provides an index of the ability of the plant to accumulate the metal with respect to the metal concentration in the substrate [50].

BCF is given by: BCF = (P/E) i:Where i denotes the heavy metal, P represents the trace element concentration in plant tissues (mg/kg dry wt.) and E represents the trace element concentration in the water (mg/l). A larger ratio implies better phytoaccumulation capability.

Translocation ability (TA) was calculated by dividing the concentration of a trace element accumulated in the root tissues by that accumulated in shoot tissues.[48]. TA is given by: TA = (Ar/As) **i:**i denotes the heavy metal, Ar represents the amount of trace element accumulated in the roots (mg/kg dry wt.) and As represents the amount of trace element accumulated in the shoots (mg/kg dry wt.). A larger ratio implies poorer translocation capability.

**Statistical analysis :** The analysis of physico-chemical characteristics and heavy metal content of soil and plant samples was done in triplicates and the data is presented as mean ± standard error.

**RESULTS AND DISCUSSION:**

Though physico-chemical features of water resource are a critical indicator of water quality, it cannot be considered completely descriptive and reliable in absence of information about ecological factors [26].The physiochemical properties of water and soil with the subsequent interval of three months are given in Table 1(a), 1(b) and 1(c)

**pH:** In all the three sites pH of waste water ranged from 7.7-8.4. The studied samples were found to be slightly alkaline in nature.pH is one of the very significant chemical characteristics of all waters, which explains certain significant biotic and abiotic ecological characteristics of aquatic systems in general [9]. But ISI (1991) range is 6.5 to 8.5.

**Temperature:** In all the three sites temperature ranged from 23-34 °C and temperature of control site was 27-34 °C. Temperature do not have any consequence on the aquatic life up to 40°C in the water bodies [17], while [24] observed that solubility of oxygen in the water increased when there was reduction in water temperature. Temperature of the water is also considered as determining factor for seasonal distribution of fauna and flora.

**BOD:** Maximum value of BOD was found at Raipura site (2.6 mg/l) in the month of September.BOD is the amount of oxygen utilized by microorganisms in consuming the organic matter in water bodies. BOD is a measure of the actual oxygen demand of wastes under laboratory conditions similar to those found in the receiving waters, and is a good indicator of biodegradability of wastes. BOD increases as the bio-degradable organic content increases in water bodies. BOD above 6 $mgL^{-1}$ in a water body is considered polluted and high BOD values are attributed to the stagnation of water body leading to the absence of self-purification [20]. It is important here to note that low BOD content is an indicator of good quality water, while a high BOD indicates polluted water. This means less oxygen is available to higher forms of aquatic life. The consequences of high BOD are the same as those for low DO. The cause of increased BOD in summer is that water microbes enhance their metabolic activity with intense amount of organic matter in the form of municipal and household discards and hence needs adequate oxygen.

**COD:** Maximum value of COD was found at Raipura site (91.50 mg/l) in the month of December. The Chemical Oxygen Demand (COD) determination is a measure of the oxygen equivalent of that portion of the organic matter in a sample that is susceptible to oxidation by a strong chemical oxidant. It is an important, rapidly measured parameter for industrial waste water studies and control of waste treatments. COD test is used to measure the load of organic pollutants in the industrial waste water. In all the samples the COD values are very much higher than 4.0 mg/L which is a maximum permissible limit according to USPH Standard.

**DO:** Maximum value of DO was found at Sazidhera site (7.5 mg/l) in the month of September. DO, is a vital parameter which describes for protection of aquatic life. High dissolved oxygen was noted during winter. It is because of greater photosynthetic rate which creates high content of DO. Generally, DO was minimum in winter and summer, but due to less rainfall, DO value was low in starting months of rainy season. DO value changes after rainy season because of the phenomenon of reoxygenation of water [19]. During winter, it is due to circulation by cooling and draw of DO [14]. Amount of low DO value has been related to the process of degradation of organic wastes involving the utilization of oxygen [22].

**TDS:** Maximum value of TDS was found at Raipura site (1613mg/l) in the month of September. The TDS is a direct measure of all the dissolved and suspended matters in water. It comprises dissolved salts, suspended particles, soil particles, discharged effluents and decomposed organic matter [42].

**Turbidity:** Maximum value of turbidity was found at Raipura site (210 mg/l) in the month of September. Suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter; plankton and other microscopic organisms cause turbidity in water. Turbidity affects light scattering, absorption properties and aesthetic appearance in a water body.

**Soil Parameters:** As metal availability also depends on the soil parameter like soil pH, organic carbon and electron conductivity. The soil parameters at contaminated sites are given in the table 2.

**pH:** pH of soil ranges from 7.42-8.24 and pH of control site (Akelgarh) was 7.8-8.4. pH of soil was towards alkaline.

**Electron conductivity:** Level of EC of control site was 0.29-0.43 dS/m. Maximum value of EC was found at Raipura site (0.74 dS/m) in the month of March. EC is a basic index to select the suitability of water for agricultural purposes [27]. EC in water is due to ionization of dissolved inorganic solids and is a measure of total dissolved solids [6] and salinity. Salts that dissolve in water break in to positive charge and negative charge ions. Dissolved solids affect the quality of water used for irrigation or drinking. They also have a critical influence on aquatic biota, and every kind of organism has a typical salinity range that it can tolerate. Moreover, the ionic composition of the water can be critical.

**Organic Carbon:** Maximum value of OC was found at Sazidehra site (0.99 %) in the month of March.

**Phytochemical Screening:** Certain biochemical parameters were studied to relate them with the plants metal detoxification capacity. Finally, estimation of biochemical parameters in samples isolated from various sites of Kota was evaluated (Table 3). Maximum amount of protein (274mg/gdw), chlorophyll (1.23mg/gdw), proline (0.67mg/gdw) were found in Sazidhera while carotenoids were observed in Raipura (0.31mg/gdw) (Table 6). Plant synthesizes primary metabolites (lipid, protein, starch, sugars, phenol etc.) for the normal growth, survival and development of itself. Preliminary phytochemical screening of plant is very useful for determination of the active constituents [37]; [39]. Contents of free proline increases with increasing concentration of the metals whereas contents of chlorophyll and carotenoids decreases.

**Heavy Metal Analysis:** Finally, presence of heavy metals (Pb, Cd, Zn and Cr) were screened in various water and soil samples using AAS at various time intervals and field study revealed that *Alternanthera philoxeroides* grew well at all the sites.

Table 4 represents the content of heavy metals in the waste water sites. The amount of Pb and Cd were found to be maximum at Raipura site (September : 4.321ppm; September :0.778ppm respectively) then at Sazidhera site (September :3.227 ppm; September: 0.194 ppm respectively). Cd and Pb which are known as toxins and carcinogens [35] ranged from 0.516 – 1.58 mg/kg and 5.5 – 9.67 mg/kg respectively. The contents of Cr and Zn were found to be highest at Raipura site (September : 6.484 ppm; December :244ppm respectively) then at Sazidhera site (September :1.631 ppm; December: 225 ppm respectively). The Cr and Zn which are required for plants for metabolic activities [40];[23] ranged from 8.86 –35.58 mg/kg and 1.03-4.65 mg/kg respectively. Maximum concentration of heavy metals was present in Raipura site. Although extensive use of chemicals is prevalent in Raipura site posing severe risk of heavy metal contamination of water.

All living beings having habitat in the intertidal zone are prone to chronic, hard changes in the environment related to life in the boundary of terrestrial and marine habitats. These variations include, biotic attacks, pollution, temperature, mechanical strain, desiccation, light (UV), variations in salinity, and regulates the allocation of organisms in the intertidal zone [13]. Stress, mainly heavy metal is known to have many effects on plant cells that cause activation of stress signaling pathways, which contain differences in cell turgor, cell volume [49]. Membrane proteins including receptor-like kinases, stretch-dependent ion (calcium) channels and redox-mediated systems [44], [25] have been recognized as osmosensors which activate downstream signaling cascades.

Table 5 and 6 represents the content of heavy metals in soil of the waste water site. The amount of Pb and Cd were found to be maximum at Raipura site (September : 4.001ppm; September :0.654ppm respectively) then at Sazidehra site (September :2.977 ppm; September: 0.181ppm respectively). The contents of Cr and Zn were found to be highest at Raipura site (September : 5878 ppm; December:244ppm respectively) then at Sazidhera site (September :1.504 ppm; December: 225 ppm respectively). Maximum concentration of heavy metals in soil was present in Raipura site. This might be due to leaching of metals to lower soil layers.

In plant samples overall Pb accumulation was higher in the root of the plants at Sazidehra site (3.48 ppm), while Cd was found to be maximum in the root of the plants at Sazidehra site (0.700ppm). Zn accumulation was found to be maximum in the shoot of the plants at Sazidehra site (277.850ppm) while Cr accumulation was maximum in the root of the plants at Sazidehra site (2.435ppm) (Table 5 and 6). The accumulation of heavy metals was greater in roots than in shoots. Even though few heavy metals when in minute quantity are vital for various metabolic mechanism in organisms, as they cause physiological stress resulting to synthesis of free radicals generally at large amount. Unlike complex organic pollutants, metal compounds are non-degradable by microorganisms or and they can be allocated by organisms and also plays role in bioaccumulation throughout the food chain, thus causing damage to human health.

## CONCLUSION

It can be thus concluded from the present study that the studied soil samples were slightly alkaline. The contents of heavy metal in the soil and water were higher than the maximum permissible limits. This study concluded that *Alternanthera philoxeroides* has potential to accumulate heavy metals and root were the preferential site of metal accumulation and thus it is recommended to be employed in the phytoremediation of these metals and may be useful for monitoring these polluting metals from the soil and wastewater. Phytoremediation using *Alternanthera philoxeroides* for soil and water environmentally sound and will continue to decrease contamination having a positive outcome for all environment and its habitants.

## ACKNOWLEDGEMENT:

P. S. acknowledges DST- Major Research Project for financial assistance and Department of Basic and Applied Sciences, Modi Institute of Management and Technology, Kota

**Table 1(a) Periodic physiochemical parameters of water estimated at Akelgarh site.**

| **Akelgarh** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **S.No.** | **Water Parameters** | **Std(IS-10500)** | **Sept** | | | **Dec** | | | **March** | | |
| | | | **A1** | **A2** | **A3** | **A1** | **A2** | **A3** | **A1** | **A2** | **A3** |
| **1.** | pH | 6.5-8.5 | 7.9 | 7.8 | 7.8 | 8.1 | 8.2 | 8.4 | 7.9 | 8.0 | 8.1 |
| **2.** | Color | | Colorless | Colorless | Colorless | Colorless | Colorless | Colorless | Colorless | Colorless | Colorless |
| **3.** | Temperature ($^oC$) | 34± | 32±2.32 | 33±2.19 | 32±2.25 | 29±2.08 | 30±2.11 | 27±1.96 | 33±2.18 | 34±2.96 | 32±2.17 |
| **4.** | BOD(mg/l) | 1.5±0.05 | 2.1±0.11 | 2.5±0.15 | 2.6±0.17 | 2.2±0.14 | 2.4±0.18 | 2.2±0.14 | 2.0±0.10 | 2.1±0.11 | 2.2±0.14 |
| **5.** | COD(mg/l) | 4.0-6.0 | 27±0.89 | 29±0.92 | 31±1.09 | 32±1.11 | 40±1.32 | 35±1.15 | 19.5±0.86 | 22±0.94 | 24±1.00 |
| **6.** | DO(mg/l) | 6.0-4.0 | 5.9±0.08 | 6.0±0.09 | 5.7±0.06 | 5.8±0.08 | 6.5±0.09 | 6.2±0.2 | 6.9±0.1 | 7.0±0.11 | 6.8±0.08 |
| **7.** | TDS(mg/l) | 500-2000 | 87.5±1.23 | 90±1.56 | 87.6±1.23 | 120±2.25 | 117±2.14 | 119±2.25 | 84±1.08 | 86±1.11 | 88±1.15 |
| **8.** | Turbidity(NTU) | 5-10 | 2 ±1.23 | 1±1.34 | 1±1.01 | 2±0.98 | 1±0.81 | 1±1.45 | 2±1.97 | 2±0.87 | 1±1.21 |

**Table 1(b) Periodic physiochemical parameters of water estimated at Sazidehra site.**

| **Sazidehra** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **S.No.** | **Water Parameters** | **Std. (IS-10500)** | **Sept** | | | **Dec** | | | **March** | | |
| | | | **S1** | **S2** | **S3** | **S1** | **S2** | **S3** | **S1** | **S2** | **S3** |
| **1.** | pH | 6.5-8.5 | 7.7 | 7.8 | 7.7 | 8.1 | 8.2 | 8.2 | 8.0 | 7.9 | 7.8 |
| **2.** | Color | | Colorless | Colorless | Colorless | Colorless | Colorless | Colorless | Colorless | Colorless | Colorless |
| **3.** | Temperature(°C) | 34± | 34±1.36 | 33±1.28 | 34±1.35 | 23±0.88 | 24±0.92 | 26±0.98 | 33±1.29 | 31±1.21 | 31±1.00 |
| **4.** | BOD(mg/l) | 1.5 | 1.8 ±0.008 | 1.7±0.006 | 1.8±0.007 | 1.9±0.009 | 1.7±0.005 | 2.0±0.008 | 2.3±0.01 | 2.0±0.009 | 2.5±0.04 |
| **5.** | COD(mg/l) | 4.0-6.0 | 50±2.27 | 47±2.19 | 48±2.22 | 35±1.17 | 38±1.23 | 38±1.22 | 55±2.36 | 53±2.31 | 55±2.35 |
| **6.** | DO(mg/l) | 6.0-4.0 | 5.2±0.08 | 5.4±0.06 | 5.5±0.07 | 5.0±0.06 | 5.6±0.07 | 5.2±0.08 | 5.1±0.05 | 5.3±0.09 | 5.4±0.1 |
| **7.** | TDS(mg/l) | 500-2000 | 390±4.23 | 383±3.87 | 373±3.82 | 360±3.75 | 355±3.46 | 359±3.49 | 387±3.91 | 380±3.81 | 390±4.23 |
| **8.** | Turbidity(NTU) | 5-10 | 21±1.51 | 25±1.89 | 23±0.89 | 15±1.43 | 18±1.17 | 20±1.76 | 21±0.95 | 23±0.86 | 22±0.81 |

**Table 1(c) Periodic physiochemical parameters of water estimated at Raipura site.**

| **Raipura** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **S.No.** | **Water Parameters** | **Std.. (IS-10500)** | **Sept** | | | **Dec** | | | **March** | | |
| | | | **R1** | **R2** | **R3** | **R1** | **R2** | **R3** | **R1** | **R2** | **R3** |
| **1.** | pH | 6.5-8.5 | 8.4 | 8.0 | 8.1 | 7.9 | 7.7 | 7.9 | 7.8 | 8.0 | 7.9 |
| **2.** | Color | | Light white/ Milky | Milky | Milky | Light white/ Milky | Milky | Light white/ Milky | Milky | Light white/ Milky | Light white/ Milky |
| **3.** | Temperature($^o$C) | 34± | 32±1.88 | 33±1.91 | 32±1.90 | 30±1.78 | 29±1.75 | 29±1.74 | 33±1.95 | 31±1.82 | 31±1.83 |
| **4.** | BOD(mg/l) | 1.5 | 2.3±0.08 | 2.0±0.05 | 2.1±0.06 | 1.7±0.008 | 2.3±0.07 | 1.9±0.009 | 1.9±0.009 | 2.4±0.07 | 2.3±0.06 |
| **5.** | COD(mg/l) | 4.0-6.0 | 88 ±1.56 | 90±1.61 | 86±1.48 | 87±1.52 | 91.50±1.55 | 85±1.43 | 77±1.35 | 79±1.44 | 81±1.46 |
| **6.** | DO(mg/l) | 6.0-4.0 | 7.5±0.05 | 7.0±0.06 | 7.2±0.04 | 6.0±0.03 | 6.5±0.05 | 5.9±0.03 | 7.2±0.04 | 6.8±0.05 | 6.5±0.05 |
| **7.** | TDS(mg/l) | 500-2000 | 1613 ±4.26 | 1551±4.08 | 1440±3.89 | 1289±3.31 | 1345±3.56 | 1401±3.79 | 980±2.25 | 954±2.14 | 1104±2.42 |
| **8.** | Turbidity(NTU) | 5-10 | 194 ±1.23 | 210±1.32 | 189±0.97 | 192±1.14 | 195±1.25 | 196±1.26 | 205±1.31 | 190±0.97 | 198±0.98 |

**Table 2 Periodic physiochemical parameters of soil estimated at Akelgarh, Sazidhera and Raipura sites.**

| | | **Akelgarh** | | | **Sazidehra** | | | **Raipura** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **S.No.** | **Soil Parameters** | **Sept** | **Dec** | **March** | **Sept** | **Dec** | **March** | **Sept** | **Dec** | **March** |
| 1. | pH | 8.09 | 8.01 | 8.24 | 7.93 | 7.84 | 7.80 | 7.42 | 7.56 | 7.91 |
| 2. | Electron conductivity (dS/m) | 0.43±0.004 | 0.29±0.002 | 0.32±0.003 | 0.68±0.006 | 0.72±0.007 | 0.74±0.007 | 0.52±0.004 | 0.58±0.005 | 0.49±0.004 |
| 3. | Organic carbon (%) | 0.68±0.006 | 0.76±0.007 | 0.73±0.006 | 0.93±0.009 | 0.97±0.009 | 0.99±0.009 | 0.57±0.005 | 0.60±0.006 | 0.49±0.004 |

**Table 3. Estimation of biochemical parameters in *Alternanthera philoxeroides* (Alligator weed)**

| **Sample** | **Protein content (in mg/gdw)** | **Chlorophyll content (in mg/gdw)** | **Proline content (in mg/gdw)** | **Carotenoids (in mg/gdw)** |
|---|---|---|---|---|
| **Akelgarh** | 65±2.29 | 0.87±0.08 | 0.37±0.04 | 0.19±0.009 |
| **Raipura** | 136±4.58 | 0.97±0.09 | 0.54±0.05 | 0.31±0.03 |
| **Sazidhera** | 274±5.33 | 1.23±.0.10 | 0.67±0.055 | 0.28±0.02 |

**Table -4 Mean concentration of heavy metals in different water samples collected from three selected sites (all data in ppm)**

| Water sample | Pb | Cd | Zn | Cr |
|---|---|---|---|---|
| **Standard** | 0.05 | 0.005 | 5.0 | 0.05 |
| **Akelgarh-1(Sep)** | 0.511±0.06 | 0.688±0.08 | 200.211±2.26 | 1.118±0.12 |
| **Akelgarh-1I(Dec.)** | 0.297±0.04 | 0.039±0.007 | 208.347±2.24 | 0.334±0.05 |
| **Akelgarh-1II(March)** | 0.548±0.08 | 0.299±0.04 | 198.577±1.89 | 1.256±0.2 |
| **Raipura I(Sep)** | 4.321±0.25 | 0.778±0.09 | 197.023±1.78 | 6.484±0.88 |
| **Raipura II(Dec.)** | 2.128±0.119 | 0.036±0.007 | 267.976±2.58 | 1.814±0.34 |
| **Raipura III(March)** | 3.825±0.23 | 0.468±0.06 | 207.088±2.22 | 4.358±0.42 |
| **Sazidhera I(Sep)** | 3.227±0.21 | 0.194±0.02 | 202.113±1.91 | 1.631±0.31 |
| **Sazidhera II(Dec.)** | 0.278±0.02 | 0.027±0.004 | 225.512±2.45 | 0.338±0.05 |
| **Sazidhera III(March)** | 1.528±0.112 | 0.089±0.01 | 212.405±2.31 | 0.798±0.09 |

WHO maximum permissible (mg/L) limit 2008.

**Table 5 and 6: Mean concentration of heavy metals in different soil and plant samples collected from three selected sites (all data in ppm)**

**Table 5:**

| Heavy Metal | | Pb | | | | | Cd | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Soil | Plant | | TF | BCF | Soil | Plant | | TF | BCF |
| | | | Root | Shoot | | | | Root | Shoot | | |
| **Standard** | | **10-70[b]** | **2mg/kg** | | | | **0.07-1.1[d]** | **0.02mg/kg** | | | |
| **Akelgarh** | **Sep.** | 0.332±0.03 | 0.502±0.05 | 0..250±0.01 | 0.498 | 1.512 | 0.646±0.06 | 0.088±0.002 | 0.032±0.001 | 0.363 | 0,136 |
| | **Dec.** | 4.001±2.17 | 3.007±0.75 | 0.197±0.009 | 0.065 | 0.751 | 0.503±0.05 | 0.099±0.008 | 0.041±0.004 | 0.414 | 0.196 |
| | **March** | 1.405±0.14 | 0.224±0.02 | 0.171±0.007 | 0.763 | 0.159 | 0.203±0.02 | 0.039±0.003 | 0.044±0.002 | 1.128 | 0.192 |
| **Raipura** | **Sep.** | 0.196±0.01 | 0..234±0.01 | 0.686±0.05 | 2.931 | 1.193 | 0.654±0.06 | 0.179±0.008 | 0.020±0.002 | 0.111 | 0.273 |
| | **Dec.** | 2.045±1.74 | 0.228±0.02 | 1.119±0.10 | 4.907 | 0.111 | 0.024±0.002 | 0.254±0.005 | 0.331±0.03 | 1.303 | 10.583 |
| | **March** | 3.051±1.98 | 0.838±0.09 | 0.909±0.10 | 1.084 | 0.274 | 0.024±0.002 | 0.078±0.006 | 0.114±0.006 | 1.461 | 3.250 |
| **Sazidhera** | **Sep.** | 2.977±2.02 | 3.447±0.88 | 0.889±0.09 | 0.257 | 1.157 | 0.181±0.01 | 0.700±0.07 | 0.045±0.002 | 0.064 | 3.867 |
| | **Dec.** | 0.250±0.02 | 3.48±0.89 | 0.200±0.01 | 0.057 | 13.924 | 0.025±0.002 | 0.644±0.05 | 0.057±0.004 | 0.088 | 25.761 |
| | **March** | 0.657±0.06 | 0.559±0.05 | 0.774±0.06 | 1.384 | 0.850 | 0.159±0.01 | 0.141±0.009 | 0.059±0.005 | 0.418 | 0.886 |

**Table 6:**

| Heavy Metal | | Zn | | | | | Cr | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Soil | Plant | | TF | BCF | Soil | Plant | | TF | BCF |
| | | | Root | Shoot | | | | Root | Shoot | | |
| Standard | | 50-100[e] | 50mg/kg | | | | 65[e] | 1.30mg/kg | | | |
| Akelgarh | Sep. | 199.313±1.71 | 197.023±1.95 | 187.976±1.78 | 0.954 | 0.988 | 5.878±2.36 | 1.631±0.15 | 0.338±0.03 | 0.207 | 0.277 |
| | Dec. | 225.512±2.22 | 218.511±2.32 | 277.850±2.69 | 1.271 | 0.968 | 1.504±0.22 | 1.118±0.12 | 0.334±0.01 | 0.298 | 0.743 |
| | March | 216.058±2.16 | 208.778±2.00 | 188.589±1.81 | 0.903 | 0.966 | 0.579±0.57 | 0.736±0.07 | 0.654±0.08 | 0.888 | 1.271 |
| Raipura | Sep. | 184.256±0.88 | 202.113±2.14 | 225.512±2.36 | 1.115 | 1.096 | 0.979±0.08 | 0.484±0.04 | 1.814±0.18 | 3.747 | 0.494 |
| | Dec. | 244.331±2.48 | 229.214±2.41 | 225.313±2.32 | 0.982 | 0.938 | 1.632±0.12 | 0.259±0.01 | 2.324±0.26 | 8.972 | 0.158 |
| | March | 218.261±2.18 | 207.113±2.24 | 174.39±1.72 | 0.842 | 0.948 | 3.645±1.88 | 1.289±0.15 | 1.838±0.25 | 1.425 | 0.352 |
| Sazidhera | Sep. | 202.003±2.00 | 210.211±2.28 | 208.347±2.31 | 0.991 | 1.040 | 0.313±0.03 | 0.886±0.08 | 1.110±0.10 | 1.252 | 2.830 |
| | Dec. | 197.116±1.68 | 197.154±1.96 | 196.658±1.91 | 0.997 | 1.000 | 0.227±0.02 | 2.435±0.25 | 0.597±0.05 | 0.245 | 10.726 |
| | March | 201.206±2.01 | 202.313±1.92 | 197.254±1.97 | 0.975 | 1.005 | 1.256± 0.19 | 1.145±0.14 | 0.455±0.03 | 0.397 | 0.911 |

a Indian standard Awasthi and European Union, 2002; b FAO/WHO, codex general standard for contaminants and toxins in foods, 1996; c World Health Organization, 2000; d World Health organization, 2004; e WHO and encyclopedia environmental science.

## REFERENCE:

[1] APHA: American Public Health Association,1995 Standard Methods: For the Examination of Water and Wastewater, APHA, AWWA, WEF/1995, APHA Publication.

[2] Arnon DI 1949 Copper enzymes in isolated chloroplasts, polyphenoxidase in *Beta vulgaris*. *Plant Physiology* 24 1-15.

[3] Ayoob S and Gupta AK 2006 Fluoride in drinking water: A review on the status and stress effects. *Critical Reviews in Environmental Science and Technology* 36 433–487.

[4] Babel S and Kurniawan TA 2004 Cr(VI) removal from synthetic wastewater using coconut shell charcoal and commercial activated carbon modified with oxidizing agents and/or chitosan Chemosphere 54 (7) *Pp* 951-967.

[5] Bates LS, Waldren RP and Teare ID 1973 Rapid determination of free proline for water-stress studies. *Plant and Soil*, 39(1), 205-207.

[6] Bhatt LR, Lacoul P, Lekhak HD and Jha PK 1999 Physico –chemical characteristics and phytoplanktons of Taudaha lake, Kathmandu. *Poll Res*. 18(4) 353-358.

[7] Boopathy R 2000. Factors limiting bioremediation technologies. *Biores. Technol*.74 63-67.

[8] Campbell PGC, Lewis AG, Chapman PM, Crowder AA, Fletcher WK, Imber B 1988 Biologically available metals in sediments, NRCC No. 27694, Ottawa,Canada

[9] Chandrasekhar S, Satyanarayana KG, Pramada PN, Raghavan P and Gupta TN 2003 Review Processing, properties and applications of reactive silica from rice husk—an overview. *Journal of Materials Science*, 38(15) 3159-3168.

[10] Chaney RL, Malik M, Li YM, Brown SL, Brewer EP, Angle JS and Baker AJ 1997 Phytoremediation of soil metals. *Curr Opin Biotechnol* 8(3) 279-284.

[11] Chapman HD 1965 Cation Exchange Capacity. In: Methods of Soil Analysis, Part 2, lack, C.A. (Ed.). American Society Agronomy, Madison, WI, USA *Pp* 891-901.

[12] Cunningham, J. L. 1997 Colored existence: Racial identity formation in light skin blacks. *Smith College Studies in Social Work*, 67(3) 375-400.

[13] Davison IR and Pearson GA 1996 Stress tolerance in intertidal seaweeds. *Journal of Phycology* 32 197-211.

[14] Dwivedi BK and Pandey GC 2002 Physicochemical factors and algal diversity of two ponds (Girijakund and Maqubara pond) Faizabad. *India. Poll. Res.* 21(3) 361-369.

[15] Esrey SA, Feachem RG et *al.* 1985 Interventions for the control of diarrhoeal diseases among young children: improving water supplies and excreta disposal facilities. *Bulletin of the World Health Organization* 63(4) 757-72.

[16] Fawell J, Bailey K, Chilton J, Dahi E, Fewtrell L and Magara Y 2006 Fluoride in drinking water. *World Health Organization (WHO), IWA Publishing, London* 97-117.

[17] Ghose BB and Basu AK 1968 observation on estuarine pollution of the Hooghly by the effluents from a chemical factory complex at Rashasa, west Bengal Env. Health 10: 29-218.

[18] Gupta N, Nafees SM, Jain MK and Kalpana S 2011 Assessment of groundwater quality of outer skirts of Kota city with reference to its potential of scale formation and Corrosivity. *E-Journal of Chemistry* 8(3) 1330-1338.

[19] HANNAN H 1979 Chemical modification in reservoir regulated streams. In the ecology of regulated streams Ed-ward J.W. *Plenamcorpo. publication* 75-94.

[20] Iqbal and Katariya HC 1995 Physico-chemical analysis and water quality assessment of upper lake of Bhopal. *International Journal of Environment and Pollution* 15 (7) 504-509.

[21] Jain A and Singh SS 2014 Prevalence of fluoride in ground water in Rajasthan State: extent, contamination levels and mitigation. *Open Journal of Water Pollution and Treatment* 1(2)

[22] Jameel AA 1998 Physicochemical studies in Vyyakandan channel water of river Cauvery. *Poll. Res.* 17 111-114.

[23] Jolly Y, Islam A and Akbar S 2013 Transfer of metals from soil to vegetables and possible health risk assessment. *Springer pub* 2:385.

[24] Joshi NC and Singh DK 2001 Effect of plant bioregulators on chilli. *Veg. Sci.* 28 (1) 74-75.

[25] Kacperska A 2004 Sensor types in signal transduction pathways in plant cells responding to abiotic stressors: do they depend on stress intensity? *Physiologia Plantarum* 122 159-168.

[26] Karr JR, Allan JD and Benke AC 2000 River conservation in United States and Canada. In P J Boon, R Davies, and G.E. Petts. Global perspective on river conservation science policy and practice, P.P -3-39. John Wiley and Sons, Chichester, England.

[27] Kataria HC, Iqubal and Sandilya AK 1995 Limno-chemical studies of Tawa Reservoir, *Indian J. of Envtl Prtcn.* 16 (11) 841-846.

[28] Kirk JTO and Allen RL 1965 Dependence of chloroplast pigment synthesis on protein synthesis: Effect of actidione. *Biochemical Biophysical Research Communications* 21 523-530.

[29] MacDonald TR, Kitanidis PK, McCarty PL and Roberts PV 1999 Effects of shear detachment on biomass growth and in situ bioremediation. *Ground Water* 37 555-563.

[30] Mandal BD, Suzuki KT 2002 Arsenic around the world: a review. *Talanta* 58 201-235.

[31] McGuire JT, Long DT and Hyndman DW 2005 Analysis of recharge induced geochemical change in a contaminated aquifer. *Ground Water* 43 518-530.

[32] Mulligan CN, Yong RN and Gibbs BF 2001 An evaluation of technologies for the heavy metal remediation of dredged sediments. *Journal of Hazardous Materials 85*(1) 145-163.

[33] Osborne DJ 1962 Effect of kinetics on protein and nucleic acid metabolism in Xanthium leaves during senescence. *Plant Plysiol.* 37 595-602.

[34] Pink, Daniel H. (April 19, 2006). "Investing in Tomorrow's Liquid Gold". Yahoo.

[35] Rajaganapathy V, Xavier F, Sreekumar D and Mandal PK 2011 Heavy metal contamination in soil, water and fodder and their presence in livestock and products: A review. *J. Environ. Sci. Technol.* 4 234-249.

[36] Salt DE, Blaylock M, Kumar NP, Dushenkov V, Ensley BD, Chet I and Raskin I 1995 Phytoremediation: a novel strategy for the removal of toxic metals from the environment using plants. *Biotechnology (N Y)*, 13(5) 468-474.

[37] Samria S. and Sarin R 2014 Quantitative estimation of phytosterol from two medicinally important plants of Cucurbitaceae. *Int. J. engg. Res. Sci.* and *Tech* 3(2) 100-104.

[38] Schreiber ME and Bahr JM 2002 Nitrate-enhanced bioremediation of BTEX-contaminated groundwater: parameter estimation from natural- gradient tracer experiments. *J. Contamin. Hydrol.* 55 29-56.

[39] Sharma P. and Sarin R 2012 *In vivo* and *in vitro* studies on stigma sterol isolated from *Pedalium murex*. *International Journal of Pharma and Biosciences* 3(4) 89-96.

[40] Sinha S, Gupta AK, Bhatt K, Pandey K, Rai UN and Singh KP 2006. Distribution of metals in the edible plants grown at Jajmu, Kanpur (India) receiving treated tannery waste water: Relation with physico-chemical properties of soil. *Environmental Monitoring and Assessment* 115 1-22[26].

[41] SR ISO 5814, "Water quality—determination of dissolved oxygen," Electrochemical Probe Method, 1990.

[42] Taheruzzama Q and Kushari DP 1995 Biomass and concentrations of macronutrients and mercury in *Azolla pinnata* R.Br. In indian ponds enriched by anthropogenic effluents. *Netherland Journal of Aquatic Ecology* 29(2) 157-160. doi:10.1007/bf02336045

[43] Trivedi RK, Khatavjainkar SB and Goel PK 1986 Charactrisation, treatment and disposal of waste water in a textile industry. *Ind. Poll. Cont.* 2 (1) 1-12.

[44] Urao T, Yakubov B, Satoh R, Yamaguchi-Shinozaki K, Seki M, Hirayama T and Shinozaki K 1999 A transmembrane hybrid-type histidine kinase in Arabidopsis functions as an osmosensor. *Plant Cell* 11(9) 1743-1754.

[45] Walkley A and Black IA 1934 An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.* 37 29-37.

[46] Wang XS and Qin Y 2006 Removal of Ni(II), Zn(II) and Cr(VI) from aqueous solution by *Alternanthera philoxeroides* biomass. *Journal of Hazardous Materials* 138(3) 582–588.

[47] West Larry (March 26, 2006). "World Water Day: A Billion People Worldwide Lack Safe Drinking Water". Wikipedia 2006

[48] Wu FY and Sun EJ 1998 Effects of copper, zinc, nickel, chromium and lead on the growth of water convolvulus in water culture. *Environ. Prot.* 21(1) 63-72.

[49] Xiong L, Schumaker KS and Zhu JK 2002 Cell Signaling during Cold, Drought, and Salt Stress. *The Plant Cell* 14(suppl 1), S165-S183.

[50] Zayed A, Gowthaman S and Terry N. 1998. Phytoaccumulation of trace elements by wetland plants: I. Duckweed. *Environ. Qual.*27, 715-21.