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# Bioremediation of soil from an industrial effluent affected system using Vermicompost

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## Abstract

Environmental pollution due to industrial effluents in Noyyal River Basin is a catastrophic illness for human health and agriculture. Various methods have been tried to remove heavy metals and other impurities. Among those methods, adsorption of heavy metals by vermicompost is a versatile technique, because of its low cost, eco-friendly and ease of operation. The physico-chemical properties of the soil shows the unremarkable change by the application of vermicompost but electrical conductivity (EC) values of the soil are greatly reduced which indicates the reduction in Total dissolved solids (TDS) in the soil. The amount of macro nutrients level is increased in the vermicompost treated soil compared to control. Soil fertility and growth of green gram plants (*Vigna radiata)* indicates that there is a significant difference with respect to control. In the present work revealed that the soil fertility is increased by treatment of vermicompost. Based on the experimental results a plausible mechanism is proposed for the adsorption of heavy metals by vermicompost.

**Keywords:** Biosorption, Vermicompost, Noyyal River region and *Vigna radiata*

## Introduction

The Noyyal sub-basin issues have been the focus of much public debate and action over the couple of decade around four districts (Tiruppur, Erode, Coimbatore and Karur) in Tamil

Nadu. The water from Noyyal River stored in orathupalayam dam, which is now one of the largest polluted dam in India. The total TDS of the dam water is close to 2000ppm and the water is not suitable for irrigation because of the high saline-sodium nature of water, which increases the hardness of the water. Recent Scientific studies were reported high concentration of heavy metals in ground water and soil including Zn, Cr, Cd, Fe and Ni due to effluent discharged by textile industries (Pandey and Singh, 2015, Wazne and Korfali, 2016, Mahmoud and Ghoneim 2016, Washington, 2012, Senthilnathan, 2005, Govindarajalu, 2003). The polluted water applied to fields, it increases the electrical conductivity (EC) and the acidic effluent makes the soil more acidic and unfit for cultivation (Senthilnathan, 2005). Several studies have documented the adverse impact of consumption of polluted water in the Noyyal River. The maximum number of cases reported was related to water-borne disease' skin and allergic diseases decrease the sperm count, diarrhea and tonsillitis, sinusitis due to people drinking and bathing the water of Noyyal River (Govindarajalu, 2003, Furn, 2004, Rajan, 2012).

Vermicompost is superior to traditional compost, which improves soil texture, structure, aeration and involves great reduction in populations of pathogenic microorganisms. Vermicompost offers nutrients that are immediately available to plants and produce faster plant growth, higher crop yields. Vermicompost is a substitute for synthetic fertilizer in soil-enriched vegetable transplant potting mixes. Urdaneta *et al*., 2008 used vermicompost as adsorbent substrate for removing Pb, Ni, and Cr from wastewaters. The highest adsorption and removal of the metals was observed for a vermicompost mass of 2 g per 500 mL using a particle size from 75 to 841 mm for Pb, Cr and Ni, and 841 till 1,192 mm for V, and the mean removal for each element was around 95% for Pb (Urdaneta *et al*., 2008).

Carrasquero-Durán and Flores, 2009 have studied the adsorption of $Pb^{2+}$ on vermicompost at 11°C, 30°C and 50°C by using Langmuir and Freundlich models. The maximum adsorption capacities were 116.3, 113.6 and 123.5 mg/g for each temperature, respectively. The differences in Fourier Transform Infrared Spectroscopy spectra of vermicompost at pH 3,8 and pH 7.0 in the region from 1,800 to 1,300$cm^{-1}$ were interpreted on the basis of carboxylic acid ionization that reduced band intensity around 1,725 $cm^{-1}$ producing signals at 1,550 and 1,390 $cm^{-1}$ of carboxylate groups.

Jadia and Fulekar, 2009 conducted a greenhouse experiment to determine the phytotoxic effect of heavy metals such as Cd, Cu, Ni, Pb and Zn on the growth of Sunflower (*Helianthus annulus*). At higher concentration (40 and 50ppm) the seed germination, root and shoot growth was affected significantly by these metals whereas at lower concentration (5 to 20 ppm) the root and shoot length was stimulated by heavy metals and increase biomass of the sunflower plant. Boni and Sbaffoni, 2009 have presented their results of a column reactor test, aiming at evaluating the performance of a biological permeable barrier made of low-cost waste materials, for $Cr^{3+}$ removal from contaminated groundwater. A 1:1 by volume mixture of green compost and siliceous gravel was tested as reactive medium in the experimental activity. Two main processes involved were: adsorption on the organic-based matrix and reduction into $Cr^{3+}$ mediated by the anaerobic microbial metabolism of the bacteria residing in green compost.

In recent years, vermitechnology has been used in industries to convert industrial wastes and sludges and into useful vermicompost for land restoration. The vermitechnology depends on many factors such as quality of raw material, pH, temperature, wetness, and ventilation condition and earthworm species used. In the present investigation envisages understanding the exact adsorption mechanism for removing the heavy metals by vermicompost from the industrial effluent affected soil in Noyyal River.

## Materials and methods

### Study Area

The Noyyal crosses three districts, Coimbatore, Erode and Karur before it reaches the river Cauvery. The river flows from west to east and are stored in the Orathupalayam dam. Hence we focus on the study area mainly in and around Orathupalayam dam.

### Soil Sampling

The soil samples were collected during morning time at the selected sites and were taken from the subsoil at 0.5-1.0 m depth. At different locations each at a distance of 200m (A), 400m (B), 600m (C), 800 (D), 1000m (E), 1200m (F) and 1400m (G) were selected for sampling in order to study the level of soil pollution due to irrigation of water from the Orathupalayam reservoir. Mixing soil from several spots is a method used to create an average sample or composite sample. It is a common procedure, but should be used judiciously to avoid skewing results. This procedure was done so that government sampling requirements are met. The soil samples were air-dried outdoors in the shade for about 24 hours and thereafter sieved at 2mm mesh size before analysis.

**Adsorbent selection**

The vermicompost used in this experiment as a bioadsorbent was purchased from a vermicompost manufacturing nursery. The physical and chemical properties of vermicompost were analyzed from Department of Soil and Environment, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Indian forest research institute, Coimbatore.

**Experimental design**

The soil samples collected from a distance of 150m (A), 300m (B), 450m (C), and 600 m (D) from the river Noyyal reservoir. The collected parent soil (Control) was mixed with vermicompost ratios of 1:3 (25% vermicompost + 75% dye affected soil), 1:2 (35% vermicompost + 65% dye affected soil), 1:1 (50% vermicompost + 50% dye affected soil) and 2:1 (65% vermicompost + 35% dye affected soil). After 25$^{th}$ day of incubation of the composition were analyzed and the fertility of the soil samples were also tested by planting different green plants.

**Soil Fertility Test**

Green plants were grown in pots in a completely randomized experimental design with five replicates. Pots with 10cm length and 20 cm breadth were used in this study. The control pots were filled by the dye affected soil and the experimental pots are filled with different ratios of dye affected soil and vermicompost. In every pot, six plants were randomly selected and the shoot length of the plants was measured for every 5 days (5$^{th}$ day, 10$^{th}$ day, 15$^{th}$ day, 20$^{th}$ day and 25$^{th}$ day). The growth of the plants was observed for the fertility of the soil for about 25 days from planting

**Statistical Analysis**

The water quality parameters of different samples and soil (control and treated) were examined and compared. The statistical analysis, like One-way ANOVA test are used for analyzing the significant difference between different soil samples before (control) and after incubation (experimental). For assessing the fertility of the soil, the shoot length of the plants was measured at the interval of 5 days upto 25 days and analyzed statistically using the Mean, Standard Deviation and Two-way ANOVA test.

## Results and Discussion

### Physico-chemical Analysis of Water Samples

The results of the physico-chemical analysis of water samples in the present study were presented in the Table.1 and Fig.1.

**Table. 1 Comparative study on Physico-chemical analysis of water samples**

| Physico-chemical Properties | A | B | C | D |
|---|---|---|---|---|
| pH | 7.20 | 7.30 | 7.20 | 7.60 |
| EC (ds/m) | 7.36 | 9.63 | 9.83 | 11.63 |
| Carbonate (mg/L) | 5.70 | 3.8 | 4.0 | 3.5 |
| Bicarbonate (mg/L) | 1.20 | 1.60 | 1.10 | 1.40 |
| Cl (mg/L) | 13.0 | 16.80 | 14.0 | 20.20 |
| $SO_4$ (mg/L) | 59.40 | 77.90 | 83.20 | 94.70 |
| Ca (mg/L) | 10.6 | 11.60 | 18.20 | 17.0 |
| Mg (mg/L) | 21.6 | 15.0 | 6.80 | 32.20 |
| Na (mg/L) | 41.64 | 68.24 | 71.33 | 64.86 |
| K (mg/L) | 0.96 | 1.46 | 1.97 | 2.24 |
| SAR | 10.58 | 18.71 | 20.18 | 13.08 |
| RSC | - | - | - | - |
| Classification | $C_5S_2R_1$ | $C_5S_2R_1$ | $C_5S_2R_1$ | $C_5S_2R_1$ |
| Mg : Ca | 2.1 | 1.29 | 0.37 | 1.89 |
| Salt Nature | $Na_2SO_3$ | $Na_2SO_3$ | $Na_2SO_3$ | $Na_2SO_3$ |
| Recommendation | VPS | PS | VPS | PS |

*SAR - Sodium Adsorption Rate; RSC - Residual Sodium Carbonate; VPS - Very Poorly Suitable; PS - Poorly Suitable*

The pH of water (7.20 - 7.60) did not show much variation in its ranges. It indicates that they were in range of water quality parameter permissible limits (Table.1). Maximum electrical conductivity (EC) value (11.63ds/m) was recorded in sample D and minimum in sample A (7.36ds/m). Maximum Carbonate level was present only in sample A. The amount of 1-2mg/l of bicarbonate was present in the water samples. Sodium Absorption Rate (SAR) ranges from 10 to 20mg/l. Residual Sodium Carbonate (RSC )was completely absent in all other samples.

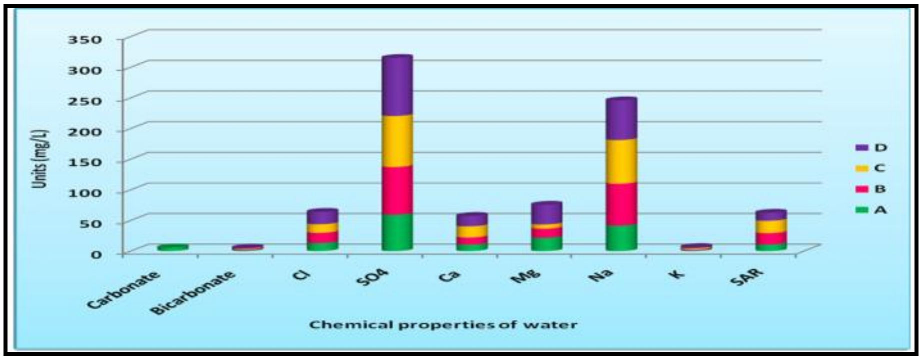



**Fig.1** Comparative studies on chemical properties of water samples

The suitability of irrigation water depends on amount and nature of salts present in the water, soil, climatic conditions and the crop species. These conditions change from place to place and therefore the classification of irrigation water is based on the amount and nature of salts in the irrigation water (Natarajan *et al.,* 1993). This finding is in accordance with our present observations that water samples B and D are poorly suitable (PS) and A and C are very poorly suitable (VPS) for irrigation purposes. Alkalinity of water could be expressed as the Residual Sodium Carbonate (RSC) value. There is a potential alkalinity hazard if there is an excess of carbonate and bicarbonate ions compared with calcium and magnesium ions. But in the current study RSC value is nil in all the cases. The level of chloride ranged from 13 to 20mg/l. The sulphate concentration in the samples was found to be more in sample D (94.70mg/l) and low in A (59.40mg/l). The level of sodium concentration was higher in sample C (71.33mg/l) and lower in A (41.64mg/l). The amount of potassium varied from 0 to 3mg/l in the samples. High calcium (18.20mg/l) and low magnesium content (6.80mg/l) was found in sample C (Fig.2)

A point of interest is that in the present study, the concentration of chloride, calcium, magnesium, sodium, potassium and sulphate were found to be increasing towards the dead-end of the discharge system. The nature of salts present in the entire sample was sodium sulphate. It is highly recommended that samples B and D are poorly suitable (PS) and A and C are very poorly suitable (VPS) for irrigation purposes.

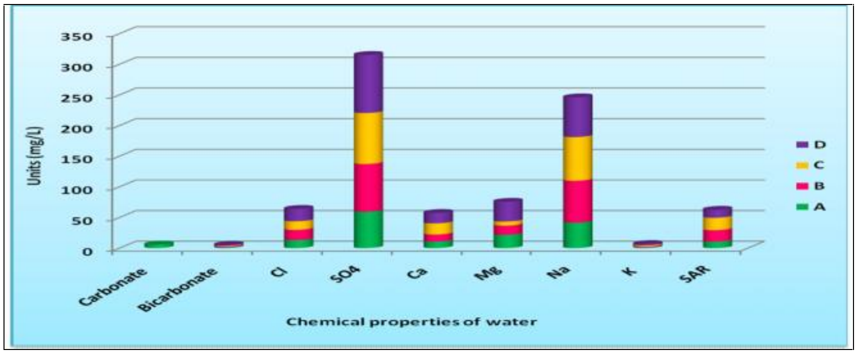



**Fig.2** Comparative studies on chemical properties of water samples

In Tamil Nadu, water intended for agricultural purposes is first analyzed for pH and electrical conductivity (EC) with the ratings given in Table. 2. From the table, it was clear that the pH of the water is normal (7.20 to 7.60) in all locations where the water samples were collected. According to the USDA system, EC > 0.5 dS/m implies medium salinity, and EC > 0.75 dS/m implies high salinity of water. But the EC values (amount of total soluble salts in water) of the water samples were in the injurious state (7.36 to 11.63ds/m). It indicated that it was not suitable to grow crops. Irrigation waters are usually classified in terms of salinity hazard (estimated from EC or TDS) and sodium hazard (SAR), in order to determine its subsequent effects on soil. The classification with respect to SAR is based primarily on the physical effects on soil but sodium-sensitive plants may suffer injury as a result of sodium accumulation at lower levels (Natarajan *et al.*,1993).

**Table.2 Tamil Nadu Classification of Irrigation Water Ratings on soil reaction (pH) and electrical conductivity (EC).**

| **pH** | | **EC** | |
|---|---|---|---|
| Rating | **Status** | **Rating** | **Status** |
| Below 6.0 | *Acidic* | *Below 1.0* | *Normal* |
| 6.0 to 8.4 | *Normal* | *1.0-3.0* | *Critical* |
| 8.5 to 8.9 | *Tending to alkaline* | *3.0 and above* | *Injurious* |
| 8.9 and above | *Alkaline* | | |

**Physico-Chemical Analysis of Soil Samples**

The physico-chemical properties of different samples of dye affected soil are shown in Table. 3 The soil texture was sandy clay loamy (**SCL**) for sample A1 and sandy loamy (**SL**) for other (**B1, C1** & **D1**) samples. The result of $CaCO_3$ content shows the A1 soil has high amount (++) of $CaCO_3$, followed by sample **B1**, moderate (+). There was no such content recorded in sample **C1** and **D1**. The EC value of the soil **B1** is more (12ds/m) and least in soil **C1** (0.68ds/m) followed by **A1** (0.95 ds/m) and **D1** (2.14 ds/m). The increase in the value of EC in the soil **B1** might be due to the different concentration of basic cations in the soil. The pH of the soil ranged from 7.9 to 8.1, the relative high pH of the soils might be due to the presence of high degree of base saturation.

**Table. 3 Physico-chemical properties of the soil samples**

| | Soil Properties | A1 | B1 | C1 | D1 | STD Critical value |
|---|---|---|---|---|---|---|
| **Physico-chemical Properties** | Texture | SCL | SL | SL | SL | |
| | $CaCO_3$ | ++ | + | - | - | - |
| | EC (ds/m) | 0.95 | 12.0 | 0.68 | 2.14 | < 1 |
| | pH | 8.1 | 8.0 | 8.0 | 7.9 | 6.0 – 8.0 |
| **Macro Nutrients (Kg/acre)** | N | 95.2 | 70 | 81.2 | 100.40 | 101–203 |
| | P | 5.0 | 5.0 | 7.75 | 7.50 | 8.0–20.5 |
| | K | 360 | 175 | 350 | 250 | >121.5 |
| **Micro Nutrients (ppm)** | Fe | 4.63 | 5.49 | 4.78 | 5.76 | 4.50 |
| | Mn | 7.69 | 6.57 | 6.57 | 6.95 | 1.0 |
| | Zn | 2.54 | 2.78 | 1.89 | 2.78 | 0.6 |
| | Cu | 1.66 | 1.45 | 1.54 | 1.57 | 0.2 |

***++ - High; + - Moderate; - - Nil; A1-Sample taken at 150m from the source; B1-Sample taken at 300m from the source;C1-Sample taken at 450m from the source; D1-Sample taken at 600m from the source.***

**Macro Nutrients**

Availability of **N** content is varied from 70 kg/acre to 100.40 kg/acre. This is because most of the soil **N** is present in organic forms. The available **P** ($P_2O_5$) content varied from 5 kg/acre to 7.75 kg/acre. All the four soil samples were medium (> 5 kg/acre) in P content. This might be due to most of the **P** in organic forms and after decomposition of organic matter humus is formed resulting in formation of a complex with Al and Fe which is a protective cover for **P** fixation with Al and Fe, reduces the **P** adsorption / Phosphate fixationon. The Status of available **K** ($K_2O$) in the soil samples ranged from 175 to 360 kg/acre. The results stated that this might be due to creation of favorable soil environment with presence of high organic matter. The aforesaid results are in accordance with the reported values by Paliwa, 1996, and Chouhan, 2001.

**Micro Nutrients**

The Fe contents in the soils ranged from 4.63 ppm to 5.76 ppm (Table.3). All the soil samples have nearest to the critical limit (4.5 ppm) as suggested by Lindsay and Norvell, 1978. The available Mn in the soil samples ranged from 6.57 ppm to 7.69 ppm. Considering 1 ppm as critical limit for Mn deficiency. All the soil samples have sufficient amount of available Mn. Soil micro nutrients like Fe, Cu, and Zn have significant correlation with available Mn.

Available Cu content in the testing soil samples ranged from 1.45 ppm to 1.66 ppm. Considering 0.2 ppm as critical limit for Cu deficiency, all the soils were found to be in adequate range of Cu content. Status of available Zn in the soil samples are varied from 1.89 ppm to 2.78 ppm. Availability of Zn in the soil samples, 0.6 ppm considered as the critical limit as suggested by Takkar and Mann, 1975.

**Physico-Chemical Properties of Vermicompost**

The pH and EC values of the vermicompost used in this present study is 7.75 and 0.7 ds/m respectively. The N, P and K contents of the vermicompost is 1.27%, 0.65 % and 1.05 % respectively. The vermicompost has 3.57 ppm of Fe, 3.64 ppm of Zn 3.34 ppm of Mn and 2.30 ppm of Cu. The values may be changed according to the species of the earthworm used, type of soil and kinds of organic materials used for preparation of compost. All the values are shown in Table.4.

**Table. 4 Physico-chemical properties of vermicompost**

| Properties | Vermicompost |
|---|---|
| pH | 7.75 |
| EC | 0.7 |
| N% | 1.27 |
| P% | 0.65 |
| K% | 1.05 |
| Fe **(**ppm**)** | 3.57 |
| Zn **(**ppm**)** | 3.64 |
| Mn **(**ppm**)** | 3.34 |
| Cu **(**ppm**)** | 3.20 |

**Note: EC -** electrical conductivity,

**Physical and chemical Properties of Soil Sample after incubation with Vermicompost**

The vermicompost amended dye affected soil samples are sandy loamy texture (SLT) except A1, which is sandy clay loamy (SCL) soil. There is no appreciable change in the soil pH even after treatment. The calcium carbonate is present in all the cases, except the sample collected from a distance of 600 m from the reservoir. The improvement of soil physical properties with the addition of vermicompost is induced by the reduction in both $Cl^-$ and $Na^+$ with the leaching water. Physico-chemical properties of the soil samples taken at 150m are given in Table.5.

**Table. 5 Physico-chemical properties of the soil samples taken at 150m from the reservoir.**

| Soil Properties | | A1 | $A_2$ | $A_3$ | B1 | $B_2$ | $B_3$ | C1 | $C_2$ | $C_3$ | D1 | $D_2$ | $D_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Physico-chemical Properties | Texture | SCL | SL | SL | SL | SL | SL | SL | SL | SL | SL | SL | SL |
| | $CaCO_3$ | ++ | ++ | ++ | + | + | ++ | - | ++ | + | - | - | - |
| | EC (dS/m) | 0.95 | 0.33 | 0.72 | 12.0 | 5.50 | 6.20 | 0.68 | 0.45 | 0.89 | 2.14 | 2.13 | 1.00 |
| | pH | 8.1 | 8.3 | 8.0 | 8.0 | 7.9 | 7.6 | 8.0 | 8.1 | 7.7 | 7.9 | 7.7 | 8.1 |
| Macro Nutrients, (Kg/acre) | N | 95.2 | 110.6 | 105 | 70 | 107.8 | 100.4 | 81.2 | 98.5 | 174.4 | 100.4 | 174.4 | 137.2 |
| | P | 5.0 | 4.5 | 9.0 | 5.0 | 4.50 | 5.0 | 7.75 | 5.75 | 9.0 | 7.50 | 6.50 | 7.50 |
| | K | 360 | 420 | 500 | 175 | 500 | 500 | 350 | 410 | 500 | 250 | 500 | 365 |
| Micro Nutrients (ppm) | Fe | 4.63 | 5.94 | 5.62 | 5.49 | 4.92 | 5.24 | 4.78 | 4.12 | 4.16 | 5.76 | 4.34 | 4.24 |
| | Mn | 7.69 | 7.12 | 6.34 | 6.57 | 6.44 | 6.41 | 6.57 | 5.09 | 5.34 | 6.95 | 5.16 | 5.16 |
| | Zn | 2.54 | 1.95 | 1.86 | 2.78 | 1.96 | 1.85 | 1.89 | 1.36 | 1.29 | 2.78 | 1.36 | 1.23 |
| | Cu | 1.66 | 1.23 | 1.29 | 1.45 | 1.22 | 1.23 | 1.54 | 1.21 | 1.24 | 1.57 | 1.19 | 1.14 |

*++ - High; + - Moderate; - - Nil; A1, B1, C1 & D1 - Control (dye affected soil); A2,B2,C2 & D2 - (1:3 ratio mixture of Vermicompost/ soil); A3,B3,C3 & D3 - 50% (1:1 ratio mixture of Vermicompost/ soil)*

When compared the EC value to **A1** control soil sample with of vermicompost incubated soils are decreased by 65 % and 24 % for **A2** and **A3** respectively (Table. 5 & Fig. 5 & 6). The nitrogen content of the treated soil is increased by 16 % and 10 % for 25% and 50% vermicompost soil respectively. Where as in the case **P** increased by 80 % in 1:1 treated soil, **K** content increased by 17 % and 39% for **A2** and **A3** respectively. With respect to micro nutrients the Fe content is increased by 25 % in both the treated soils, whereas Zn and Cu content of soils is decreased by around 25 % compared to the control soil. The macro Nutrient and micro nutrient content in control and Vermicompost treated soil samples at 150 m from the reservoir are shown in Fig.3.

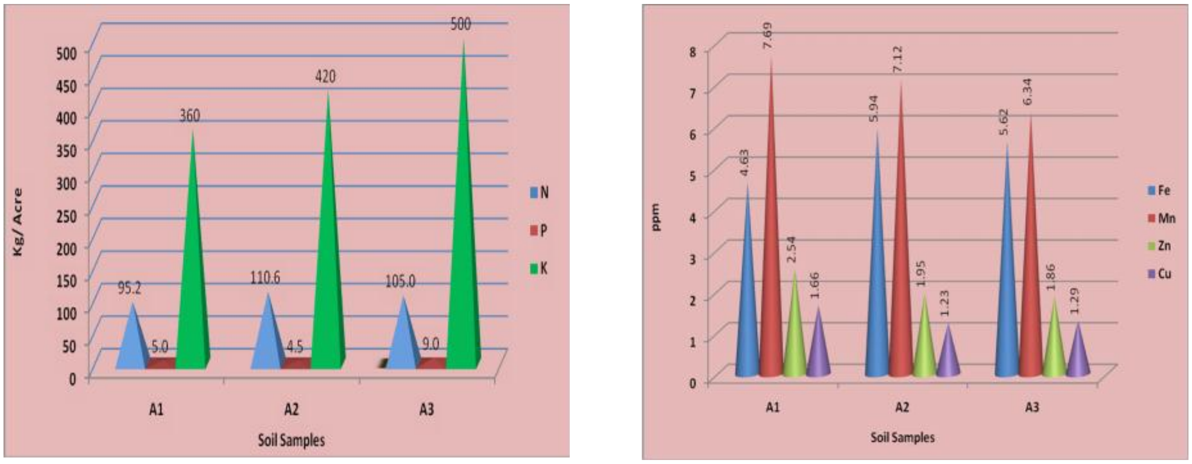



**Fig.3 NPK and Micro nutrient content in control and Vermicompost treated soil samples are collected at 150 m from the reservoir.**

When compared to **B1** control soil sample, the EC value of vermicompost incubated soil samples were decreased by 54 % and 48 % for B2 and B3 respectively. The nitrogen content of the treated soil was increased by 54% and 43 % for 25% and 50% vermicompost treated soil respectively. Where as in the case P and Mn it was observed that there was no appreciable changes in the P and Mn content of the treated soils. K content of the treated soil was increased by 186% in both the treated soils. With respect to micro nutrients the Fe has decreased by 10 % and 5 % in B2 and B3 respectively . In the case of Zn about 30 % reduction in the both the treated soils samples whereas the Cu content of both the treated soils have decreased by around 16 % compared to the control soil (Table. 5 and Fig. 4).

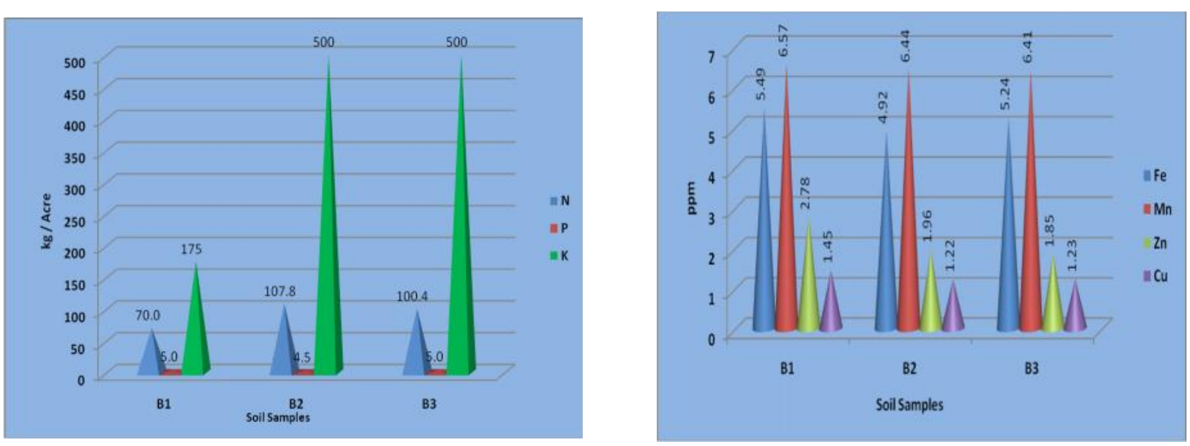
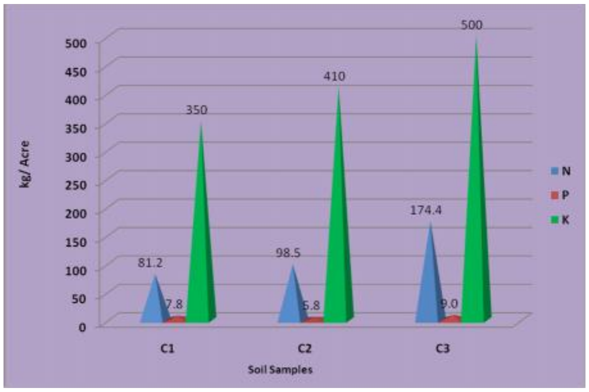



**Fig.4 NPK and Micro nutrient content in control and Vermicompost treated soil samples are collected at 300 m from the reservoir.**

Table. 5 and Fig.5 clearly indicated that compared to C1 control soil sample, the EC value of vermicompost incubated soil samples were decreased by 34 % in C2 and reverse in the case of C3 with 31 %. The nitrogen content of the treated soil was increased by 21% and 115 % for 25% and 50% vermicompost soil respectively. Where as in the case C2 it was observed that there was decrease in P concentration by 26 % but reverse in the case C3 by 16 %. In both the treated soil samples it was observed that there was a reduction in Mn and Cu concentration by 21 %. K content of the treated soil was increased by 17 % and 43 % for C2 and C3 respectively. With respect to micro nutrients the Fe has decreased by 13% and Zn has decreased by 30 % in both the treated soils.



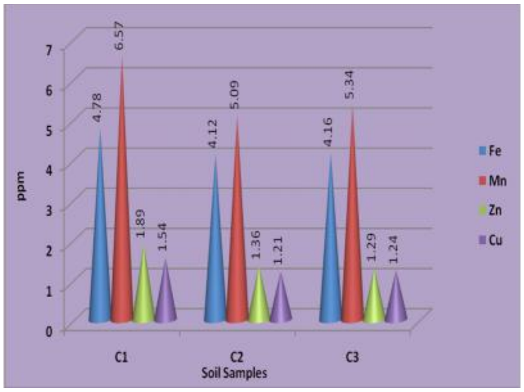
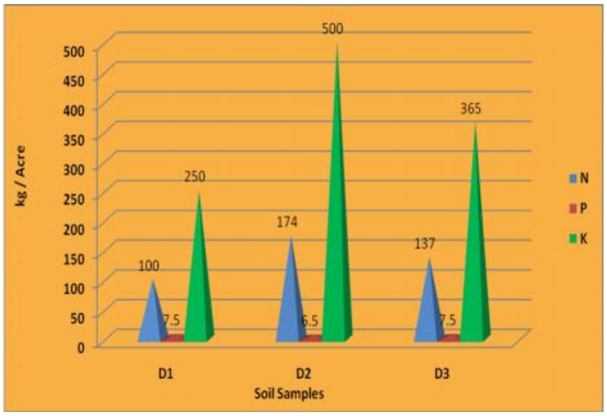




**Fig.5 Macro Nutrient (NPK) and Micro nutrient content in control and Vermicompost treated soil samples are collected at 450 m from the reservoir.**

When compared to D1 control soil sample, the EC value of 50 % vermicompost incubated soil was decreased by 53% and there was no remarkable changes in 25 % treated soil. The nitrogen (N) content of the treated soil was increased by 74 % and 37 % for 25% and 50% vermicompost soil respectively (Table- 10 and Fig.- 8). Whereas in the case P it was decreased by 13% in D2 and reverse is the in D3 with 16 %. K content of the treated soil was increased by 100 % and 46% for D2 and D3 respectively. With respect to micro nutrients the Fe, Mn and Cu had come down by around 25 % in both the treated soils, likewise Zn content in both the treated soils have decreased by around 53% compared to the control soil ( Table.5 and Fig. 6).



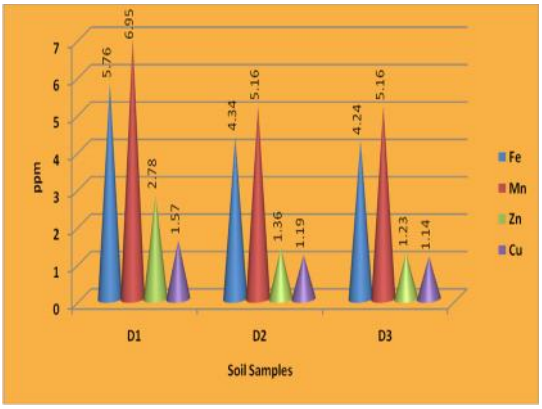




**Fig.6 Macro Nutrient (NPK) and Micro nutrient content in control and Vermicompost treated soil samples are collected at 600 m from the reservoir.**

Vermicompost mixed soil in both the treatments in sample A alone had an increased iron content compared to control whereas in the other samples significant decrease in the amount of iron was noted. Other micronutrients such as manganese, zinc and copper shows a drastic reduction in their contents in the vermicompost treated soil compared to control

Application of vermicompost at rate of 1:3 and 1:1 ratio significantly increased the nitrogen (N) content over the control soil. The available nitrogen content was more in 25% altered soil compared to 50% vermicompost. The soil content of available phosphorus ($P_2O_5$) increased with individual additions of 50% vermicompost and decreased in 25% vermicompost compared to control. The highest content of available potassium ($K_2O$) is found in the sample treated with 25% vermicompost, whereas the lowest was recorded in the control. The available nitrogen and potassium increased with the increase of the mixing ratio of vermicompost. These increases were more pronounced in the soil treated with 25% vermicompost treatment for N and 50% treatment for P.

Vermicompost can supply the full requirement of major nutrients for plant growth i.e. N, P, K; secondary nutrients i.e. Cu, Zn, Mn and Fe. The average nutrient content of vermicompost is much higher than in other types of compost reported by (Singh *et al*., 2006).

**ANOVA for Macro and Micro Nutrient**

**Table. 6** ANOVA data for macro nutrient (NPK) and micronutrient content of different soil samples

| Sample | | MACRO NUTRIENT NPK ANOVA | | | | MICRO NUTRIENT NPK ANOVA | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Sum of Squares | Degree of freedom | Mean Square | F | Sum of Squares | Degree of freedom | Mean Square | F |
| **A** | ***Between Groups*** | 3943.30 | 2 | 1971.65 | 0.0399* | 0.28 | 2 | 0.1393 | 0.0188* |
| | ***Within Groups*** | 296742.63 | 6 | 49457.11 | | 66.74 | 9 | 7.42 | |
| | ***Total*** | 300685.93 | 8 | | | 67.02 | 11 | | |
| **B** | ***Between Groups*** | 28624.22 | 2 | 14312.11 | 0.2968* | 0.46 | 2 | 0.2306 | 0.0383* |
| | ***Within Groups*** | 289322.77 | 6 | 48220.46 | | 54.19 | 9 | 6.0211 | |
| | ***Total*** | 317946.99 | 8 | | | 54.65 | 11 | | |
| **C** | ***Between Groups*** | 10448.62 | 2 | 5224.31 | 0.1122* | 1.38 | 2 | 0.6928 | 0.1496* |
| | ***Within Groups*** | 279429.93 | 6 | 46571.66 | | 41.69 | 9 | 4.6324 | |
| | ***Total*** | 289878.56 | 8 | | | 43.07 | 11 | | |
| **D** | ***Between Groups*** | 17409.07 | 2 | 8704.54 | 0.2359* | 4.43 | 2 | 2.2152 | 0.4519* |
| | ***Within Groups*** | 221362.01 | 6 | 36893.67 | | 44.12 | 9 | 4.9024 | |
| | ***Total*** | 238771.08 | 8 | | | 48.55 | 11 | | |

*The tabulated value of F for given dfat 1% level is 5.  * Values are not significant at 1% level.*

The tabulated value of F for the given degrees of freedom (i.e. 2 and 6), at 1% level is 5.14 which is higher than the calculated values of all variables of samples A1, A2 and A3 = 0.0399; B1, B2 and B3 = 0.2968; C1, C2 and C3 = 0.1122; D1, D2, D3 and D3 = 0.2359 with respect to NPK content.

The tabulated value of F for the given degrees of freedom (i.e. 2 and 9), at 1% level is 4.26 is higher than the calculated values of all variables of samples (A1, A2and A3 = 0.0188; B1, B2 and B3 = 0.0383; C1, C2 and C3 = 0.1496; D1, D2, D3 and D3 = 0.4519) with respect to difference micro nutrient content. The hypothetical values revealed that there is no significant difference no macro nutrient composition (NPK) and micro nutrient composition (Fe, Mn, Zn and Cu) of soil samples with respect to control and experimental are given in Table. 6.

**Effects of Vermicompost on fertility of the soil**

From the Table. 7, the maximum growth rate is observed in sample $C_2$ (29.48cm), followed by $A_1$ (29.05cm) and finally $D_1$ (22.03cm) after 25 days of harvesting. In sample C1, 25% vermicompost treated soil showed better growth compared to other treatments. Plant height (cm) of green gram plants increased significantly in soil mixed with the Vermicompost in the ratio of 1:3 (25% vermicompost and 75% soil) compared to other treatments. The relative increase of shoot length of the gram plants differed significantly between the studied treatments.

These findings are supported by previous reported works (Roberts *et al*., 2007, Lazcano C and Domínguez J 2010). The variability in the effects of vermicompost may depend on the cultivation system into which it is incorporated, as well as on the physical, chemical and biological characteristics of vermicompost, which vary widely depending on the original feedstock, the earthworm species used, the production process, and the age of vermicompost (Roberts *et al*. 2007. Rodda *et al*. 2006, Warman and AngLopez, 2010).

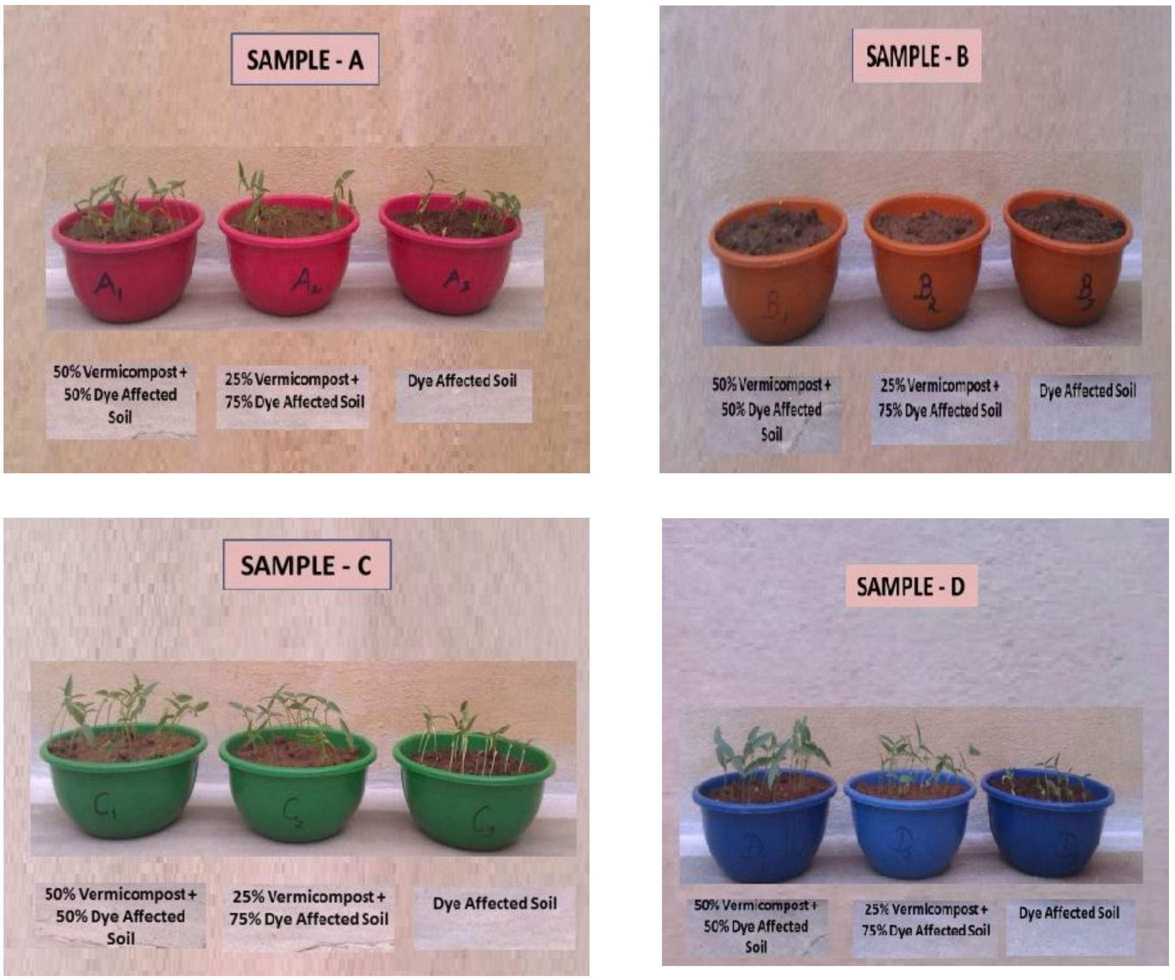



**Fig. 7 Effect of mixtures of vermicompost and dye affected soil on growth of green gram plant (*Vigna radiata*) after fifth day of treatment**

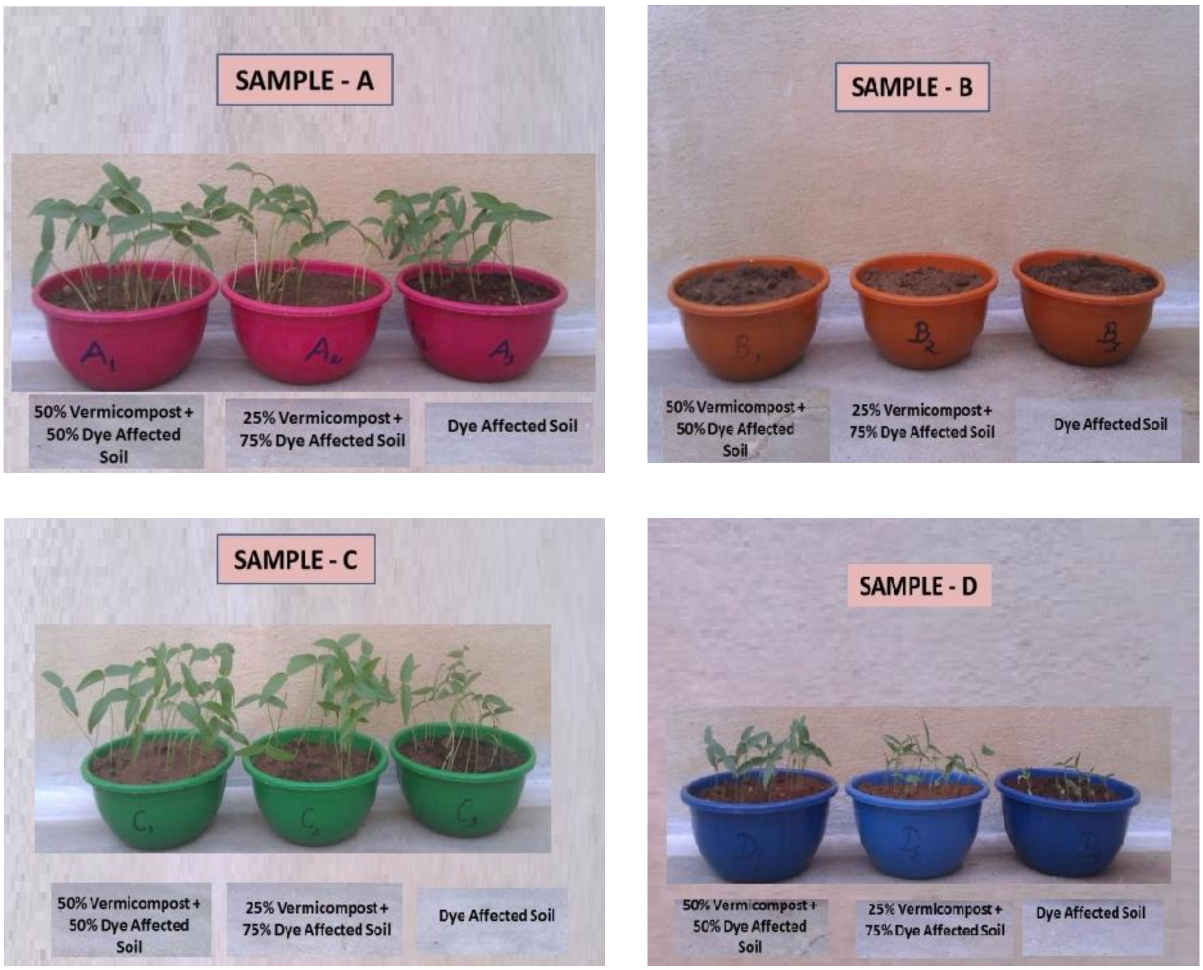



**Fig. 8 Effect of mixtures of vermicompost and dye affected soil on growth of green gram plant (*Vigna radiata*) after tenth day of treatment**

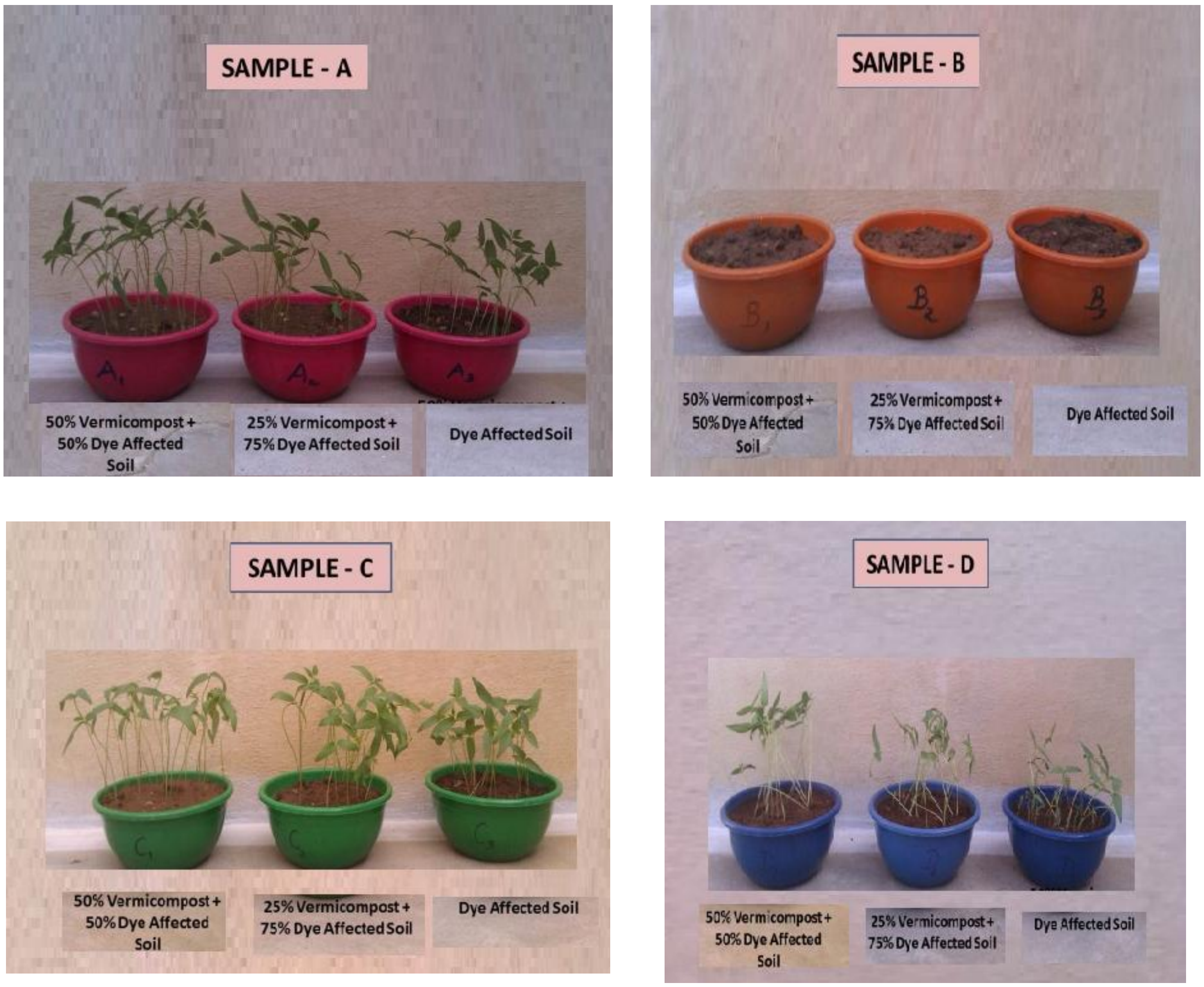



**Fig. 9 Effect of mixtures of vermicompost and dye affected soil on growth of green gram plant (*Vigna radiata*) after fifteenth day of treatment**

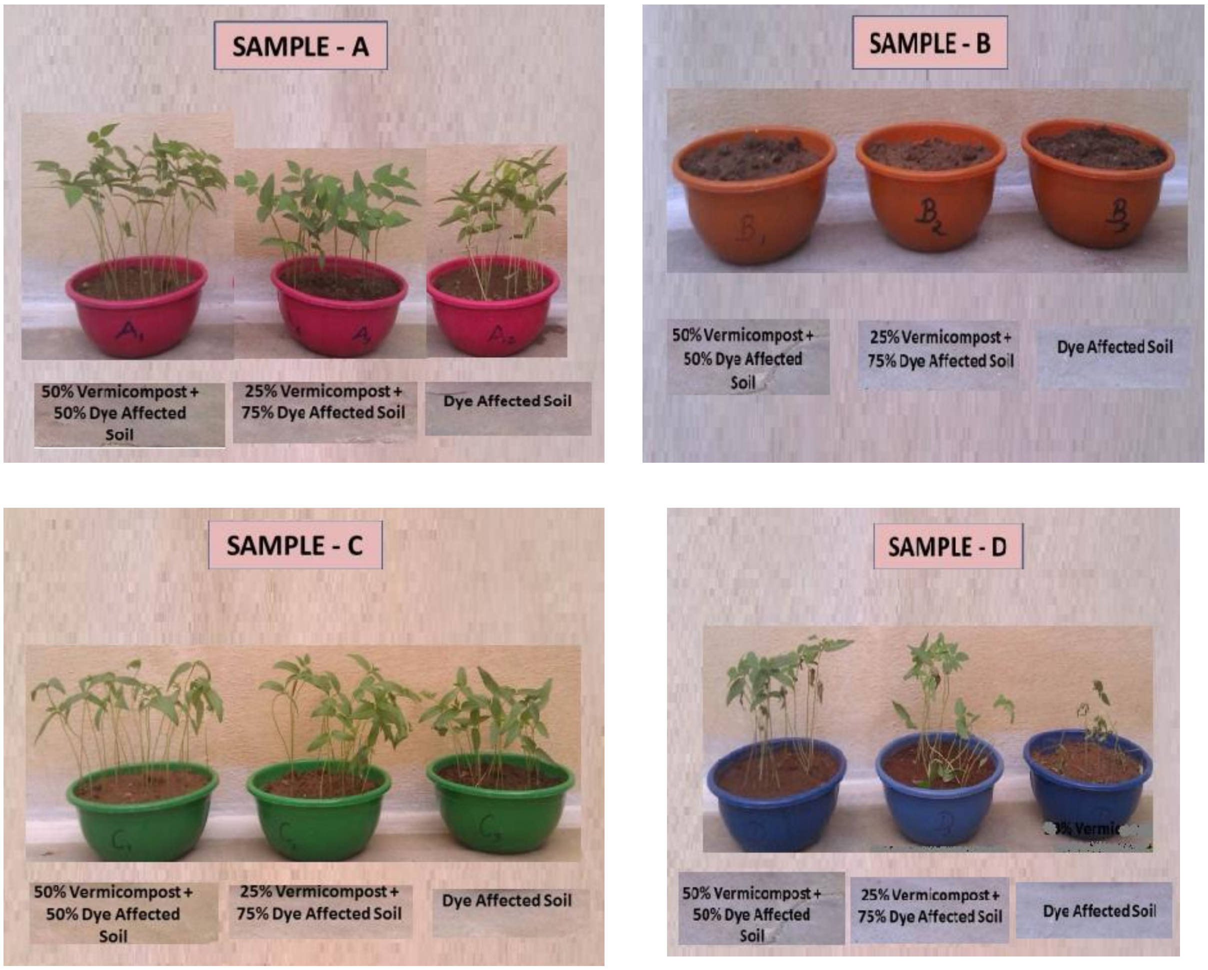



**Fig. 10 Effect of mixtures of vermicompost and dye affected soil on growth of green gram plant (*Vigna radiata*) after twenty days of treatment**

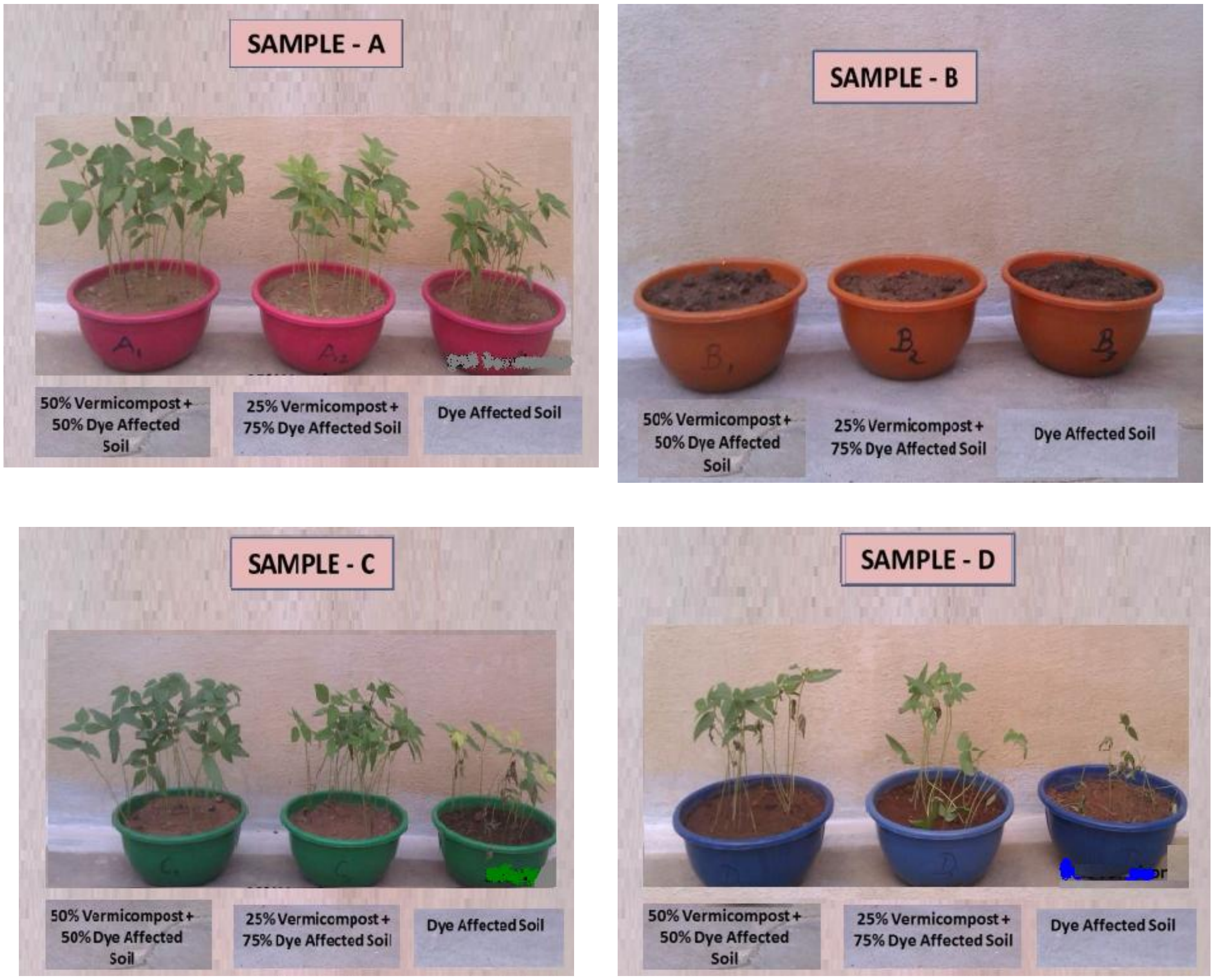



**Fig. 11 Effect of mixtures of vermicompost and dye affected soil on growth of green gram plant (*Vigna radiata*) after twenty fifth day of treatment**

**Table. 7 The average shoot length (in cm) of the green gram plants grown in different ratio vermicompost mixed with soil at different time intervals (5, 10, 15, 20 & 25 days).**

| Shoot length in cm | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Days** | **5** | | | **10** | | | **15** | | | **20** | | | **25** | | |
| Sample | **1** | **2** | **3** | **1** | **2** | **3** | **1** | **2** | **3** | **1** | **2** | **3** | **1** | **2** | **3** |
| **A** | 4.4 ±0.6 | 3.6 ±0.5 | 3.5 ±0.5 | 10.5± 0.6 | 8.6 ±0.5 | 8.0 ±0.2 | 17.1 ±0.3 | 14.1 ±0.2 | 14.1 ±0.2 | 26.0 ±0.2 | 23.0 ±0.7 | 22.4 ±0.5 | 29.1 ±0.2 | 27.0 ±1.4 | 23.5 ±0.6 |
| **B** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **C** | 3.4 ±0.4 | 4.5 ±0.4 | 3.5 ±0.5 | 9.5 ±0.5 | 12.4 ±0.6 | 8.5 ±0.5 | 15.6 ±0.6 | 18.5 ±0.4 | 14.6 ±0.4 | 25.6 ±0.6 | 27.6 ±0.6 | 16.6 ±0.5 | 27.0 ±0.7 | 29.5 ±0.6 | 18.0 ±0.2 |
| **D** | 3.6 ±0.5 | 5.5 ±0.5 | 4.3 ±0.4 | 8.6 ±0.5 | 11.4 ±0.6 | 9.6 ±0.6 | 15.6 ±0.5 | 18.5 ±0.6 | 12.0 ±0.7 | 18.5 ±0.5 | 19.0 ±0.2 | 15.0 ±0.6 | 22.0 ±0.2 | 19.6 ±0.6 | - |

**Mechanism of adsorption of heavy metals by vermicompost**

Vermicompost is a humus act as adsorbent substrate for removing Pb, Ni, V, Cd, Cu, Zn and Cr from waste water and it supplies a suitable mineral balance to improve the nutrient availability and could act as complex-fertilizer granules to the agricultural soils and involves great reduction in populations of pathogenic microorganisms. In the present experimental study to shows the oxidized humic acid present in vermicompost with oxidizing binding site. The positive metal ions attracted to broken bonds at the site of the oxidation, create sites for micronutrients and microflora to attach. Every oxidized humic acid molecule can potentially accommodate upto six metal ions (Fig.12).

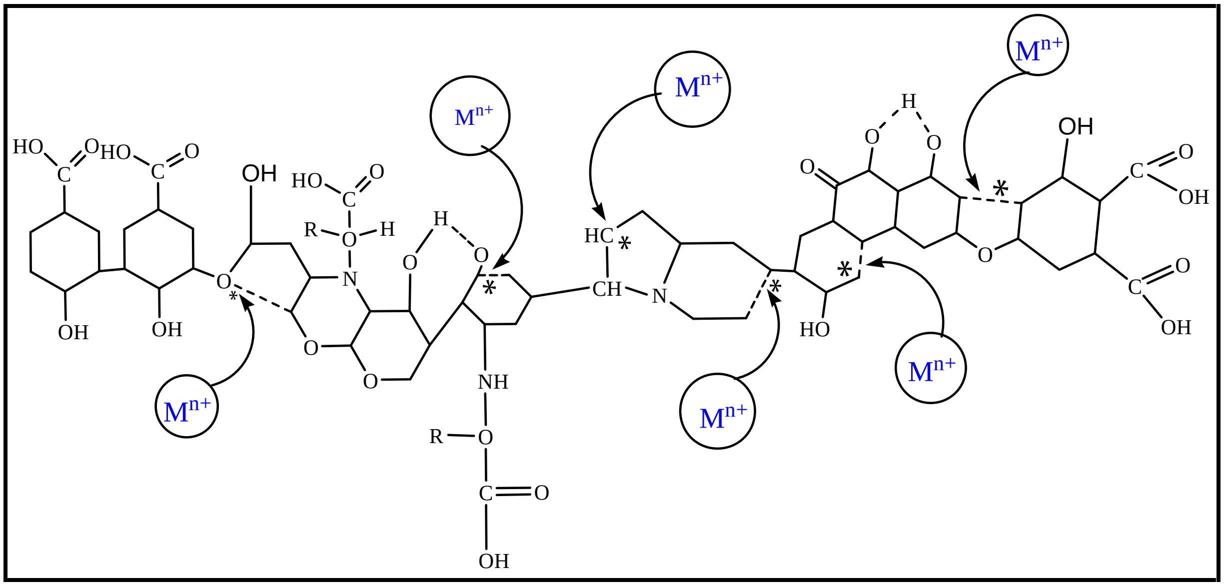



**Fig.12 Structure of humic acid**

## Conclusion

The soil and water samples are collected from four locations each at a distance of 150m (A), 300m (B), 450m (C) and 600m (D) from the reservoir are selected for the present study. The pH of water does not show much variation and the concentration of other salts in the water samples are found to be increasing towards the dead-end of the discharge system. It is highly recommended that water samples poorly suitable (PS) and very poorly suitable (VPS) for irrigation purpose. By the application of vermicompost and the EC values are greatly reduced in the vermicompost added soil which indicates the reduction in dissolved solids concentration. However the macro nutrients (N and K) levels are greater in the vermicompost treated soil compared to control. Soil fertility and growth of green gram plants with respect to control soil and vermicompost treated soil indicated that there is a significant difference among the control and experimental plants.  The Shoot length of the *Vigna radiata* showed greater effect by mixing vermicompost to the effulent affected soil, hence the shoot length of the green gram plant is increased by the addition of vermicompost to the control soil. In the present experimental study is an evidence for adsorbing the heavy metal ions by the vermicompost due to the presence of oxidized humic acid in vermicompost. The positive metal ions attracted to broken bonds at the site of the oxidation, create sites for micronutrients and microflora to attach. Every oxidized humic acid molecule can potentially accommodate upto six metal ions.

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