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# Effects of Industrial Solid Waste Toxicity on Soil & Soil Amendments

**Srinivas J[1], Purushotham AV[2] and Murali Krishna KVSG[1]**

*[1]Department of Civil Engineering, JNTU Kakinada, Andhra Pradesh, India*
*[2]MSN Degree College, Kakinada, Andhra Pradesh, India*
*srinivas.msc18@gmail.com*

**ABSTRACT**

*The Industrial solid waste samples were collected at the outlet of release channel of the Oil and Gas Industry at Kakinada, air-dried and was brought to the laboratory. The soil amendments were prepared for as Control, Amendment 1, 2, 3 and 4. The pH of the amendments decreased from A1 to A4 (6.82 to 5.57) over control soil (7.32) whereas the Electrical conductivity has increased from 0.268 millimhos /cm in A1 to 0.698 millimhos /cm in A4. Organic carbon content, Organic matter, Potassium and Manganese in the amendments showed trend from A1 to A4, whereas, Nitrogen, Phosphorus, Aluminium and Iron have shown trend. The Copper, Zinc, Iron and Manganese concentrations were increased from the Control and Amendment 1 to Amendment 4 because of the toxicity of the industrial solid waste extracts.*

**Key words:** Andhra Pradesh, East Godavari, Heavy Metals, Industrial solid waste, Soil and Soil amendments

## INTRODUCTION

Waste is a by-product of life. High standards of living and ever increasing population have resulted in an increase in the quantity of wastes generated. Industrial Solid Waste (ISW) is generally a combination of industrial activities refuse which is generated from the industrial community. Among the multitude of the environmental problem existing in the urbanizing cities of developing countries, ISW management and its impact on ground water quality have become the most prominent in the recent years. Due to lack of efficient Industrial solid waste management system and improper dumping of ISW as open landfills, the soil in the Kakinada city is found to be contaminated in various places.

Management of industrial solid waste is distinctly different from the approach used for municipal waste [1]. There is a lot of similarity between the characteristics of the waste from one municipality or one region and another, but for industrial waste, however, only a few industrial sectors or plants have a high degree of similarity between products and waste generated [2]. The contamination of Industrial solid wastes including mine wastes has become a worldwide concern. Several authors have shown a relationship between atmospheric elemental deposition and elevated elemental concentrations in plants and top soils, especially in cities and in the vicinity of emitting factories [3-7].

Worldwide environmental pollution is continuously increasing. Industrial and agricultural activities have contributed to the increasing occurrence of heavy metals in the ecosystem [8]. Heavy metals such as manganese (Mn), copper (Cu), iron (Fe), zinc (Zn) and nickel (Ni) are essential mineral nutrients for higher plants. Cu also induces toxicity in tissue concentrations slightly above its optimal levels [9].

Copper is one of the most abundant trace metal and micronutrient of great importance in agricultural production and occurs as $Cu^{+}$ and as $Cu^{2+}$ [12]. Cu is also required as a co-factor of Cu-Zn superoxide dismutase [13]. A vital component of both photosynthetic (plastocyanin) and respiratory electron chains (cytochrome oxidase). Copper is also essential to human life and is required for various biological processes [14]. The average abundance of copper in the earth's crust is recorded as 24 to 55 ppm [15]. Zinc is slowly oxidised in moist air. Zinc is an essential element for the plant growth. Weathering produces $Zn^{2+}$ which can substitute for $Mg^{2+}$ in silicate minerals in the soil. Zinc (Zn) is an essential micronutrient that affects several metabolic processes of plants [16]. The common ores of iron are both iron oxides, and these can be reduced to iron by heating them with carbon in the form of coke. Coke is produced by heating coal in the absence of air. Coke is cheap and provides both the reducing agent for the reaction and also the heat source. The most commonly used iron ores are hematite, $Fe_2O_3$ and magnetite $Fe_3O_4$. The higher oxides ($MnO_2$, $Mn_2O_3$, and $Mn_3O_4$) can all be reduced to manganese oxide (MnO) by carbon monoxide, but this lower oxide can be reduced to the metal only at elevated temperatures by carbon. Accumulation of excessive manganese (Mn) in leaves causes a reduction of photosynthetic rate [17]. Mn is readily transported from root to shoot through the transpiration stream, but not readily remobilized through phloem to other organs after reaching the leaves [18]. Necrotic brown spotting on leaves, petioles and stems is a common symptom of Mn toxicity [19].

## STUDY AREA

The Kakinada city is the capital of East Godavari District of Andhra Pradesh on the central east coast of India. The area under study Kakinada is located at 16°56′N 82°13′E. It has an average elevation of 2 metres (6 ft) and many areas of the city are below sea level. The present study deals with the Effects of Heavy Metal Industrial Solid waste toxicity on Soil and Soil Amendments in Kakinada, Andhra Pradesh, India.

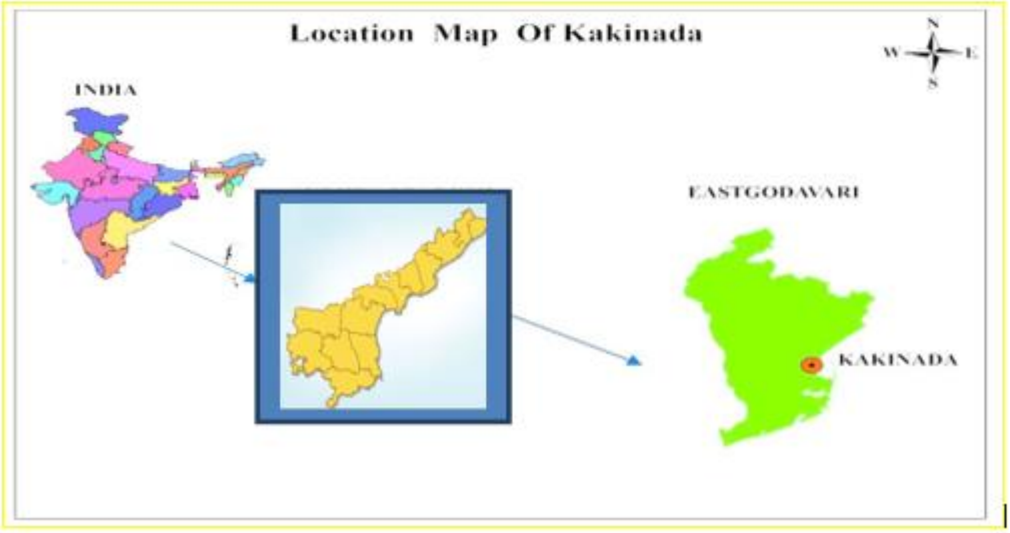


**Fig. 1 Location Map of Kakinada**

## MATERIAL AND METHODS

### Industrial Sludge Waste Collection

The Industrial solid waste samples were collected at the outlet of release channel of the Oil and Gas Industry at Kakinada; air-dried and was brought to the laboratory.

### Seed Material Collection

The seeds of (Brinjal) *Solanum melongena L.* variety: were procured from an Agricultural Cooperative Centre at Kakinada, East Godavari district, Andhra Pradesh.

### Soil and Sampling

Soil from the conventional crop fields near the (ISW) Oil and Gas factory (East Godavari District, Andhra Pradesh, Kakinada) was selected and used in the experimental studies on *Solanum melongena* L. Soil samples were collected randomly from the field in five replicates and air dried for 72 *hours*, powdered, sieved through 2 *mm* sieve and subjected to Physico- chemical analysis.

### Pot Experiment

All the experiments pertaining to the pot culture were conducted in the experimental farm and the ground water sample was used for this experiment.

The solid sludge was powdered and mixed with black soil and farm yard manure in the ratio 2:1, placed in 15*kg* pots in different concentrations (5%, 10%, 30% and 50%). The pots were watered with tap water at the rate of 2 *l* /pot/*d*.
In each pot seeds were dibbled in equal distance and depth. A fortnight after only 3 seedlings were retained in each pot at equal distance and the rest were removed. For each concentration seven replicates were maintained making a total of 21 plants, including control. Observations were made on 20 plants for each concentration. Plants harvests were made on 21, 51 and 95 days. As three harvests were studied a total of 105 pots were maintained and for each harvest a total of 35 pots were taken at random for analysis. For each harvest and for each concentration monoliths of plants were dug out from seven pots including that of control. Care was taken to keep intact the entire root system during washing.

## RESULTS

### Physico – Chemical Analysis of Control Soil

The control soil for the present work has been collected from the agricultural fields of *Kakinada, East Godavari district of Andhra Pradesh*. The soils were air dried and brought to the laboratory and analysed for its Physico-Chemical characteristics. The parameters analysed include Colour, pH, Electrical Conductivity, Organic Carbon, Organic matter, Available Nitrogen, Available Phosphorus, Available fraction of Potassium, and Chlorides. In addition to these, heavy metals like Copper, Zinc, Iron and Manganese are reported. The data is shown in Table -1.

### Physical Characteristics of Control Soil

The soils are black in colour, with a texture of silty clay to clay. It is sticky and plastic in nature.

### Chemical Characteristics of the Control Soil

The control soil is neutral in character and had a pH of 7.32 with 0.263 *millimhos /cm* of Electrical Conductivity. The Chemical analysis showed that the control soil contained 5.36% of Organic Carbon and 7.89% of Organic matter. The control soils recorded 0.182 *µg/g* of available nitrogen; 2.83% of available phosphorus and 3.82% of exchangeable potassium; 2.8% of Aluminium; Nickel 8.10 *(µg/g)* reported. The control soil also contained and 8.1 *(µg/g)* of Iron, 43.3 *(µg/g)* Zinc, Copper 3.1 *(µg/g)* and 80.91 *(µg/g)* Manganese reported. (Table -1 & 2 and Fig. 2).

### Physico–Chemical Analysis of Amended Soils on Day 1:

The control soil has been blended with requisite amounts of ISW to get 5%, 10%, 30% and 50% Industrial sludge waste amended soils for the pot studies. The amended soils were air dried and subjected to analysis for their Physico-Chemical characteristics. The Physico-Chemical characteristics of the Soil Amendments are presented in Table - 3. The Control and the fours soil amendments are herein after referred to as shown below:

**Table -1 Physico- Chemical Characteristics of Control Soil**

| S. No. | Parameter | Characteristic/ Value |
|---|---|---|
| 1 | Copper *(µg /g)* | 3.1 |
| 2 | Zinc *(µg /g)* | 43.3 |
| 3 | Iron *(µg /g)* | 8.1 |
| 4 | *Manganese (µg /g)* | 80.91 |

**Table -2 Amendment Codes and Composition**

| S. No. | Amendement Composition | Amendement Code |
|---|---|---|
| 1 | 100% Control Soil | ***Control (C)*** |
| 2 | 95 % Control Soil + 5 % ISW | ***Amendment 1 ($A_1$ soil)*** |
| 3 | 90 % Control Soil + 10 % ISW | ***Amendment 2 ($A_2$ soil)*** |
| 4 | 70 % Control Soil + 30 % ISW | ***Amendment 3 ($A_3$ soil)*** |
| 5 | 50 % Control Soil + 50 % ISW | ***Amendment 4 ($A_4$ soil)*** |

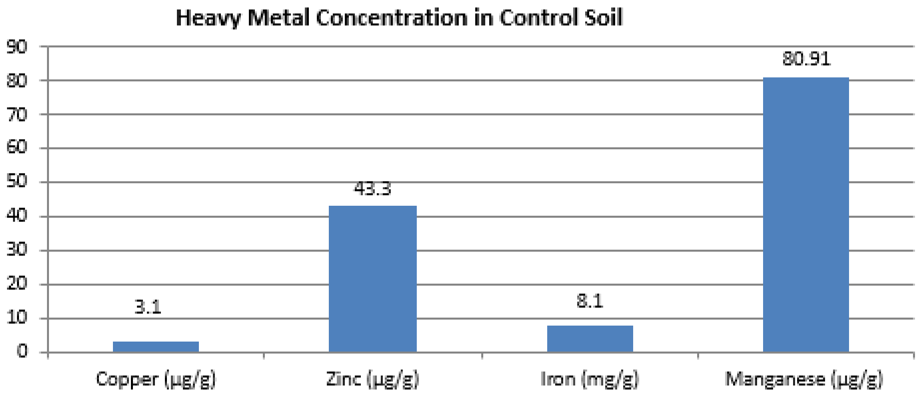


**Fig. 2 Heavy Metal Concentrations in Control Soil**

### Amendment 1 ($A_1$ soil):

The ***A₁*** soil is neutral in character and had a pH of 6.82 with 0.268-*milli mhos/cm* of Electrical Conductivity. The Chemical analysis showed that the $A_1$ soil contained 5.12% of Organic Carbon and 8.6% of Organic matter. The $A_1$ soil recorded 0.16% of available nitrogen; 2.67% of available phosphorus and 3.62% of exchangeable potassium. The $A_1$ soil also contained 3.5% of Aluminium and 8.30% of Iron followed by other heavy metals, like Cu, Ni, Zn, and Mn was recorded at 9.8 µg/g, 6.8 µg/g, 44.8 µg/g and 83.91 µg/g.

### Amendment 2 ($A_2$ soil):

The $A_2$ soil is slightly acidic in character and had a pH of 6.76 and recorded 0.268-*milli mhos/cm* of Electrical Conductivity. The Chemical analysis showed that the $A_2$ soil contained 4.95% of Organic Carbon and 8.36% of Organic matter; 0.284% of available nitrogen; 2.72% of available phosphorus and 3.6% of exchangeable potassium. The $A_2$ soil also contained 3.8% of Aluminium and 8.70 µg/g of Iron and 84.12 µg/g of Mn followed by other heavy metals, like Cu, Ni, and Zn, was recorded at 9.9 µg/g, 6.2 µg/g, and 45.2 µg/g.

**Amendment 3 ($A_3$ soil):**

The $A_3$ soil is acidic in character and had a pH of 6.11 and recorded 0.576-*milli mhos/cm* of Electrical Conductivity. The Chemical analysis showed that the $A_3$ soil contained 3.5% of Organic Carbon and 6.04% of Organic matter; 0.411% of available nitrogen; 2.90% of available phosphorus and 2.68% of exchangeable potassium. The $A_3$ soil also contained 3.8% of Aluminium and 8.09 *µg/g* of Iron and 85.46 *µg/g* Mn followed by other heavy metals, like Cu, Ni, and Zn, was recorded at 10.6 *µg/g*, 5.1 *µg/g* and 46.4 *µg/g*.

**Amendment 4 ($A_4$ soil):**

The $A_4$ soil is acidic in character with a pH of 5.57 and recorded 0.698-*milli mhos/cm* of Electrical Conductivity. On Chemical analysis, $A_4$ soil recorded 3.42% of Organic Carbon and 5.88% of Organic matter; 0.532% of available nitrogen; 3.057% of available phosphorus and 1.80% of exchangeable potassium. The $A_4$ soil also contained 3.9% of Aluminium and 9.21*µg/g* of Iron and 86.11*µg/g* Mn followed by other heavy metals, like Cu, Ni, and Zn was recorded at 10.29µg/g, 4.2 µg/g, and 47.6 µg/g.

The pH of the amendments decreased from $A_1$ to $A_4$ (6.82 to 5.57) over control soil (7.32) whereas the Electrical conductivity has increased from 0.268 *millimhos /cm* in $A_1$ to 0.698 milli*mhos /cm in* $A_4$. Organic carbon content, Organic matter, Potassium and Manganese in the amendments showed trend from $A_1$ to $A_4$, whereas, Nitrogen, Phosphorus, Aluminium and Iron have shown trend. The Copper, Zinc, Iron and Manganese concentrations were increased from the Control and Amendment 1 to Amendment 4 because of the toxicity of the industrial solid waste extracts.

**Table -3 Physico- Chemical Characteristics of Control & Amended Soils**

| S. No. | Parameter | C | $A_1$ | $A_2$ | $A_3$ | $A_4$ |
|---|---|---|---|---|---|---|
| 1. | pH | 7.32 | 6.82 | 6.76 | 6.11 | 5.57 |
| 2. | Conductivity *(millimohs)* | 0.263 | 0.268 | 0.268 | 0.576 | 0.698 |
| 3. | Organic Carbon *(%)* | 5.36 | 5.12 | 4.95 | 3.59 | 3.42 |
| 4. | Organic Matter *(%)* | 7.89 | 8.60 | 8.36 | 6.04 | 5.88 |
| 5. | Available Nitrogen *(%)* | 0.182 | 0.160 | 0.284 | 0.411 | 0.532 |
| 6. | Available Phosphorus *(%)* | 2.83 | 2.670 | 2.729 | 2.908 | 3.057 |
| 7. | Available Potassium *(%)* | 3.82 | 3.62 | 3.60 | 2.68 | 1.80 |
| 8. | Chlorides *(µg/g)* | 240.38 | 252.1 | 276.8 | 291.2 | 316.0 |
| **Soil Metals** | | | | | | |
| 9. | Aluminium, *(%)* | 2.4 | 3.5 | 3.8 | 3.8 | 3.9 |
| 10. | Nickel *(µg/g)* | 8.10 | 6.8 | 6.2 | 5.1 | 4.2 |
| 11. | Copper *(µg/g)* | 3.1 | 9.8 | 9.9 | 10.6 | 10.29 |
| 12. | Zinc *(µg/g)* | 43.3 | 44.8 | 45.2 | 46.4 | 47.6 |
| 13. | Iron *(µg/g)* | 8.1 | 8.3 | 8.7 | 8.9 | 9.21 |
| 14. | Manganese *(µg/g)* | 80.91 | 83.91 | 84.12 | 85.46 | 86.11 |

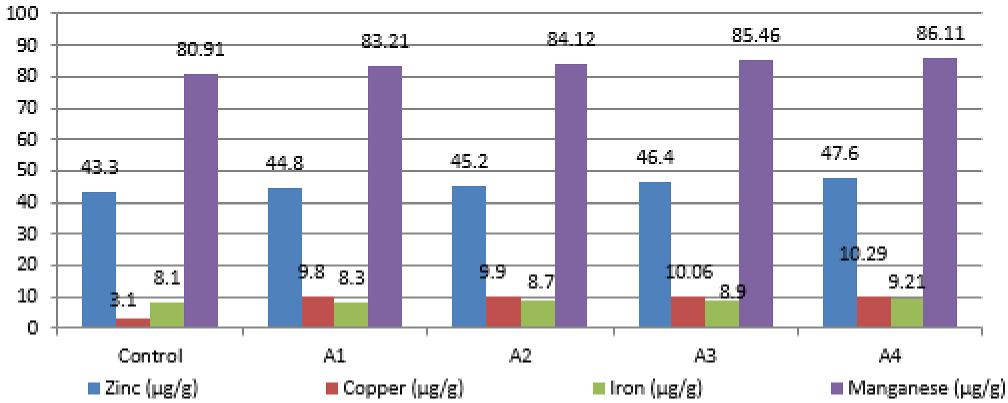


**Figure- 3: Heavy Metal Concentrations in Soils Amended with ISW**

## CONCLUSION

The results of the present study urge further research on all agricultural crops grown in the surroundings of the solid waste dumpsites of all industries in different regions and soils. The results of this study stress the need for environmental awareness, adequate regulations and proper management of waste sites by the local municipal authorities. There is a need to check industrial pollution by implementing strictly the pollution control laws and strict control on the disposable of untreated effluents around the industries needs to be enforced. High concentration of heavy metals and other hazardous substances in the groundwater quality in the Kakinada city in particular need to be evaluated. Proper methods of Industrial solid waste disposal have to be undertaken to ensure that it does not affect the environment soil contamination around the area or cause health hazards to the people, Flora and Fauna living there.

Some of the recommendations are as follows –

- Urban local bodies should identify the areas from where industrial solid waste is generated.
- Encourage research on remediation of Soil and Industrial solid waste contaminated sites in industrial area of Kakinada.
- Screening of all agricultural crops to understand their response to the ISW contamination and also make necessary strategies to advise the farmers.

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