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Accumulation levels of heavy metals in field area vs. experimental study soils

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ABSTRACT

The soil sample from field area and 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 samples were collected at near to oil and gas industry for experimental study. The soil amendments were prepared for as Control, Amendment 1, 2, 3 and 4. 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 milliohms/cm in A_1 to 0.698 milliohms/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. 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.

Keywords: Andhra Pradesh, East Godavari, heavy metals, industrial solid waste, soil and soil amendments.

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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.

Management of industrial solid waste is distinctly different from the approach used for municipal waste (Freeman, 1989). 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 (Woodard, 2001). Nowadays industrial solid waste management is an important part of industry. The number of contaminated sites, which are polluted by industrial and hazardous waste, are increasing in developing countries (LaGrega et al., 2001). Heavy metals can accumulate in living organisms and cause various diseases (Alam et al., 2009). Heavy metal toxicity is potentially dangerous because of bioaccumulation though the food chain and this can cause hazards effects on livestock and human health (Aycicek et al., 2008; Aschner, 2002). 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 (Andersen et al., 1978; Pilegaard, 1978; Harrison and Chirgawi, 1989; Larsen et al., 1992; Sanchez-Camazano et al., 1994).

MATERIALS AND METHODS

Study area

The Kakinada city is the capital of East Godavari District of Andhra Pradesh on the central east coast of India (Figure 1). The area under study Kakinada is located at 16°56′ N and 82°13′ E. It has an average elevation of 2 m (6 ft) and many areas of the city are below sea level. The present study deals with the accumulation levels of heavy metal concentrations in field area vs. experimental study soils in Kakinada, Andhra Pradesh, India.

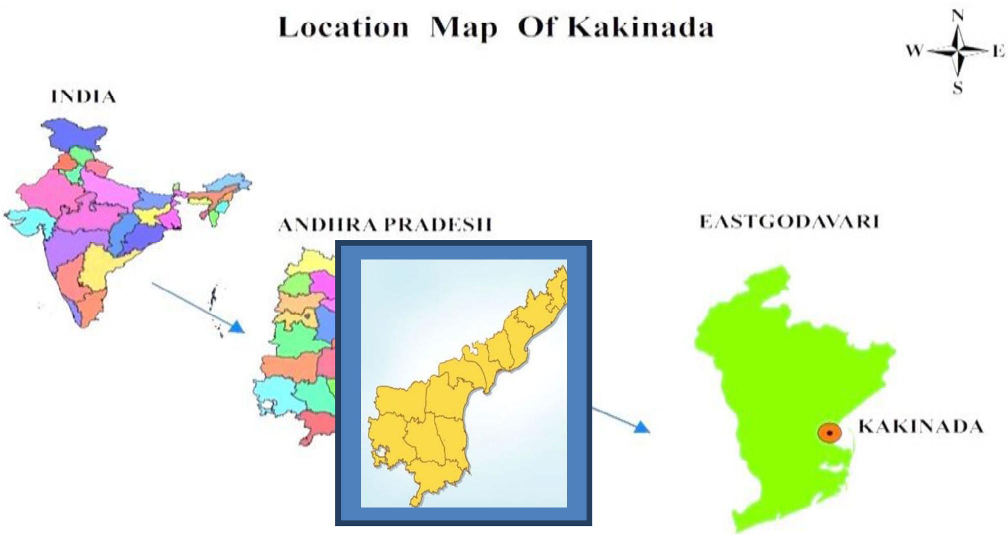

Figure 1. Location map of Kakinada.

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. The samples were air-dried and were 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.

Field area soil sample

Field area soil samples were collected from the field area of North side of the open land in an industrial area of Kakinada, East Godavari district. Soil sample were sampled at the same locations along with the plant sample at 15 cm depth rooting zone and mixed to form composite samples at location and also observed the heavy metal analysis for estimation of Heavy metals in the *Solanum* plant parts.

Experimental study soils

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 was 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 h, powdered, sieved through 2 mm sieve and were 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 was used for this experiment. The solid sludge was powdered and mixed with black soil and farm yard manure in the ratio 2:1, and were 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. After a fortnight 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 harvest was 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

Field area soil sample

The soil sample was slightly acidic with a pH of 5.25 with 0.686 *millimhos/cm* of Electrical Conductivity. The chemical analysis showed that the field area plant soil sample contained organic carbon, organic matter, total nitrogen, total phosphorus and exchangeable potassium as 0.190, 0.321, 0.640, 0.026 and 0.009%, respectively. The grown *Solanum melongena* L. in field area (behind the Industry) (Figure 2). The soil sample recorded high concentrations of heavy metals, like copper (900.03 µg/g), zinc (12.32 µg/g), iron (632.3

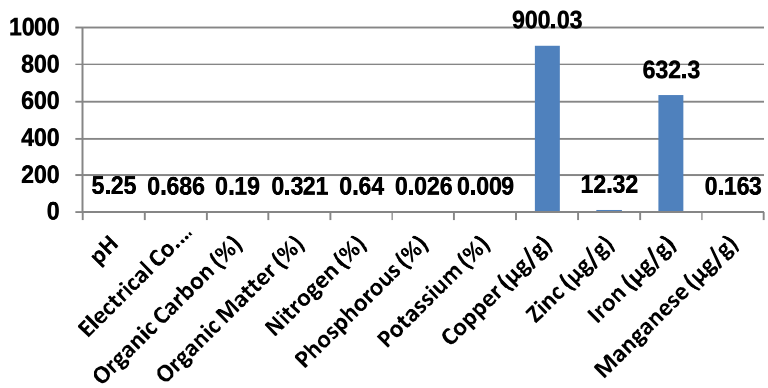

Figure 2. Field area soil sample after harvesting the final 95th day.

µg/g*)*, and manganese (0.163 µg/g).

Level of heavy metal concentrations in field area soil sample

900.03 > 632.3 > 12.32 > 0.163 (µg/g)
Cu > Fe > Zn > Mn

Soil sample analysis

The soil sample was slightly acidic and had a pH of 5.21 with 0.686 millimhos/cm of Electrical Conductivity. The chemical analysis showed that the soil sampled from the field area where the plants were grown contained organic carbon, organic matter, total nitrogen, total phosphorus and exchangeable potassium as 0.190, 0.321, 0.640, 0.026 and 0.009%, respectively (Figure 3). The soil sample contained heavy metals, like copper 18.16*%*, zinc 12.50 µg/g, Iron 9.30*%,* manganese 0.181 (µg/g).

Experimental soil sample

Level of heavy metal concentrations in experimental study soil sample after harvesting (final 95th day)

899.16 > 630.5 > 12.51 > 0.161 (µg/g)
Cu > Fe > Zn > Mn

Amendment 1 (A_1 soil):

The A_1 soil was neutral in character and had a pH of 6.82 with 0.268-*milli mhos/cm* of Electrical Conductivity (Table 1). 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 as 9.8, 6.8, 44.8 and 83.91 µg/g, respectively.

Amendment 2 (A_2 soil):

The A_2 soil was slightly acidic in character and had a pH of 6.76 and recorded 0.268-*milli mhos/cm* of Electrical Conductivity (Table 1). 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 as 9.9, 6.2, and 45.2 µg/g.

Amendment 3 (A_3 soil):

The A_3 soil was acidic in character and had a pH of 6.11 and recorded 0.576-*millimhos/cm* of Electrical Conductivity (Table 1). 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 Aluminum and 8.09 µg/g of Iron and 85.46 µg/g Mn followed by other heavy metals, like Cu, Ni, and Zn as 10.6, 5.1 and 46.4 µg/g.

Amendment 4 (A_4 soil):

The A_4 soil was acidic in character with a pH of 5.57 and recorded 0.698-*millimhos/cm* of Electrical Conductivity (Table 1). 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 as 10.29, 4.2 and 47.6 µg/g (Figure 4).

Table 1. Amendment codes and composition.

S. no	Amendment composition	Amendment 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)

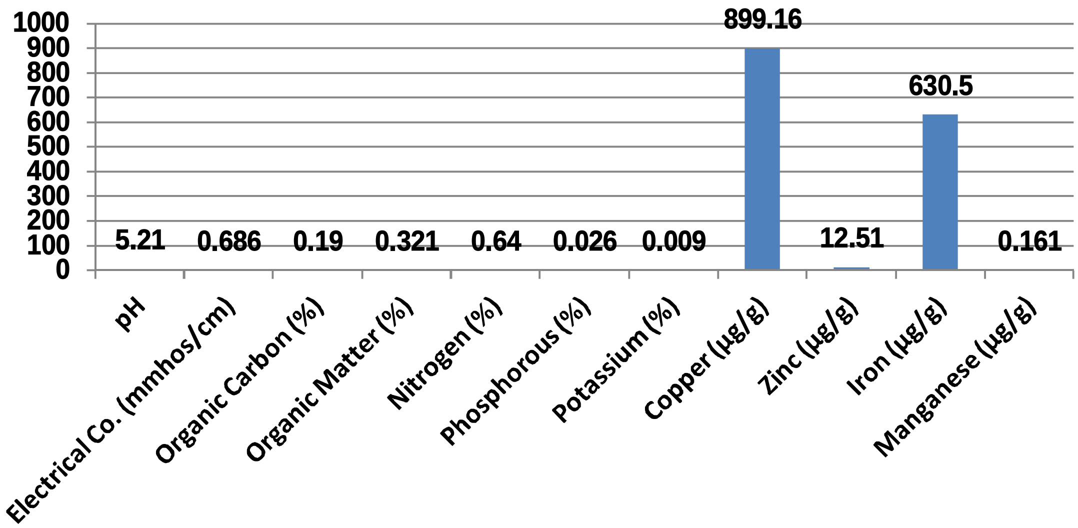

Figure 3. Differences between the field area soil sample and soil sample analysis after harvesting the final 95th day (field area study vs. experimental study).

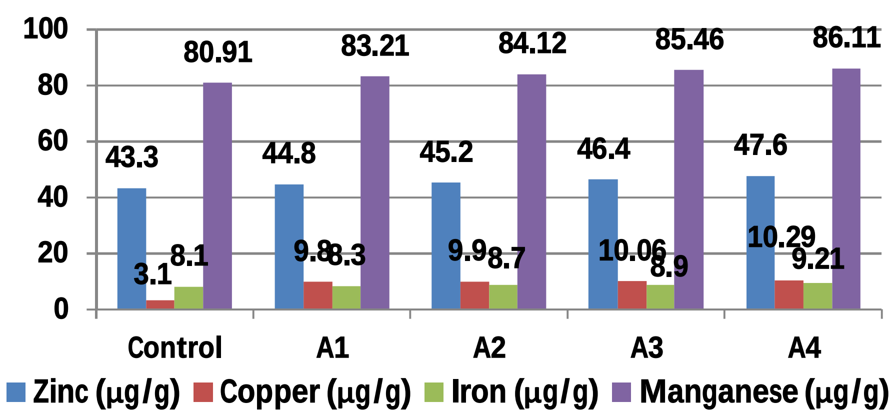

Figure 4. Heavy metal concentrations in soils amended with ISW.

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 *millimhos/cm in* A_4 (Table 2). Organic carbon content, Organic matter, Potassium and Manganese in the amendments showed showed a decreasing trend in A_1 and have shown an increase in the remaining A_2, A_3 and A_4 amendments and also Nitrogen and Phosphorus have shown the same trend when compared with the control whereas Aluminium and Iron have shown an increase in all the amendments when compared with the control.

DISCUSSION

Level of Heavy Metal Concentrations in Field area Soil sample (Field Study)

900.03 > 632.3 > 12.32 > 0.163 (µg/g)
Cu > Fe > Zn > Mn

Table 2. Physico-chemical characteristics of control and amended soils.

S. no.	Parameter	Soil and soil amendments				
		C	***A₁***	***A₂***	***A₃***	***A₄***
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.	Aluminum (%)	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

Level of heavy metal concentrations in after harvesting the (Final 95th day) soil sample (experimental study)

899.16 > 630.5 > 12.51 > 0.161 (µg/g)
Cu > Fe > Zn > Mn

The Copper, Zinc, Iron and Manganese concentrations have increased from the Control and Amendment 1 to Amendment 4 which may be due to the toxicity of the industrial solid waste extracts.

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 disposal of untreated effluents around the industries needs to be enforced. High concentration of heavy metals and other hazardous substances in the groundwater samples of 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 as the soil contamination around the area could cause health hazards to the people, flora and fauna living there.

RECOMMENDATIONS

1. Urban local bodies should identify the areas from where the industrial solid waste is generated.
2. Inventorisation of industries could be attempted through SPCBs or industries department for characterization of wastes.
3. Urban local bodies may undertake collection, transportation and disposal of solid waste on cost recovery basis as per existing rules and may identify suitable sites for final treatment and disposal of industrial solid waste as per existing rules and regulations.
4. Screening of all agricultural crops to understand their response to the ISW contamination and also make necessary strategies to advise the farmers.
5. Encourage research on remediation of ground water, soil and industrial solid waste contaminated sites in the industrial area of Kakinada.

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