# Phytoremediation studies on contaminated soils of some industrial areas of Visakhapatnam, A.P

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**Abstract-Elemental analyses of the soil samples collected from eight different industrial sites of Visakhapatnam revealed varying concentrations of heavy metals. Among the soil samples tested samples of Hindustan Zinc Ltd. ( HZL) contained highest concentrations of Zinc, Lead, Copper Cadmium, Arsenic andChromium *visa vis* other soil samples tested. The relative metal concentrations in HZL site were found in the following order Zn=8030 > Pb = 6960 > Cu=292 > Cd=221 > As=111 > Cr=108. Nonetheless, other soil samples collected from industrial regions of Parrysugar, Essar, HPCL, Coramandel, Pharmacity and Govada sugar factory also contained more than one metal in higher concentrations i.e. above acceptable levels.**

**Enrichment coefficient data reveal that the efficacy of hyper accumulation of metals in in-situ weed species was in the following order Alternanthera sessilis > Cynodon dactylon > Tridax procumbens > Datura stramonium > Catheranthes roseus whereas, Brassica nigra lead the list among ex-situ weeds followed by Datura metel > Pisum sativum > Ipomia cornia.**

**Keywords, Heavy metals, Phytoremediation, Enrichment coefficient**

## INTRODUCTION

Visakhapatnam, a North-East Coastal district of Andhra Pradesh, with an establishment of 320 large and medium scale industries in the core area, has become the hub of industrial activity and endorsed as one of the most polluted industrial cluster in Andhra Pradesh. Hindustan Zinc Ltd., Hindustan polymers, Hindustan Petroleum Corporation Ltd., Coramandal Fertilizers Ltd., Andhra Cement Company and Coastal Chemicals Ltd. located in the city play pivotal role as the major source of pollution**.** Improper waste disposal practices by these industries resulted in continuous addition of wide range of organic and inorganic contaminants rendering the surrounding areas with degraded quality of soil (Baker and Walker, 1990, Williams, G.M., 1988). More importantly, the heavy metals released into the ecosystem, can further lead to the ramifications of geo-accumulation, bioaccumulation and bio-magnifications. Hence, the problems associated with contaminated sites now assume increasing prominence and remedial steps to improve the quality of these contaminated soils has gaining the attention of scientific community all over the world. Phytoremediation offers low tech, low cost and eco-friendly technology in the reclamation of the degraded soils (Black H., 1995, Berti, W.R. and Cunningham, S.D., 2000, Garbisu, C., and Alkorta, I., 2001, Reeves, R.D. and Baker, A.J.M., 2000, Susaral *et al* 2002). Present study was conducted to determine the heavy metal accumulation potential of ten plant species by *in-situ* and four plant species by *ex-situ* analysis.

## MATERIAL AND METHODS

Site selection:

To assess the contamination levels industrial sites located in and around Visakhapatnam city, soil samples from eight different industrial sites were collected and garden soil of Andhra University, Visakhapatnam was used as negative control (Table 1). 50 mg of each of different soil samples were shade dried and digested in a solution of Hydrofluoric acid: Nitric acid: Percloric acid (7:3:1, *v/v*) at 80-90$^0$C for 15 minutes. The solution was allowed to evaporate by raising temperature to 120$^0$C until the solution becomes transparent. The final volume was added with 20 ml with nitric acid and distilled water (1:1, *v/v*), heated for10 -15 minutes and filtered through 0.25 µ filter paper. Each sample was further diluted by adding 250 ml distilled water.15 ml of each sample is used for ICP-MS analysis. Metal concentrations of each sample obtained from ICP-MS analysis and are converted to ppm (mg/kg) concentration by using the following formula.

$$\frac{\text{ICP-MS reading x dilution sample}}{\text{Weight of soil sample}}$$

Basing on the data obtained on eight tested samples for heavy metal contaminants, the soil of sewage disposal area of Hindustan Zinc Ltd. (HZL), Visakhapatnam was selected as the phytoremediation study area. Contaminated soil samples (HZL) and garden soil were analyzed for various physicochemical parameters like pH, Organic matter, water holding capacity etc., which influence and affect the solubility and availability of metals to plants (Table 2).

Collection of plant species:

Ten different plant species viz., Tridax procumbens, Alternanthera sessilis, Cynodon dactylon, Parthenium hysteroporous, Datura stramonium, Ricinus communis, Catheranthus roseus, Cleome viscosa, Abutilon indicum and Scoparia dulcis growing in the vicinity of HZL sewage disposal area were collected in-situ. *Tridax procumbens* growing in the University area was collected as control sample. In *ex-situ* experiments, healthy seedlings of four different plant species *viz.*, *Brassica nigra*, *Datura metel*, *Ipomea cornea* and *Pisum sativum* were simultaneously raised in pots filled with the contaminated HZL site soil, nurtured under controlled conditions, along with seedlings of *Brassica nigra* raised in pots with University garden soil used as control. After six weeks of culture in the pots, plants were uprooted, brought to lab for further analysis. The collected plant species are washed with running tap water followed by distilled water to remove extraneous matter. After washing the plants were oven dried at $65^0$C till constant weight. Metal estimations were done in both *in-situ and ex-situ* collected plant species following same methodology described earlier for soil samples. All the readings were taken in five replicates (*n*=5).

*Enrichment Coefficient (EC)*

Enrichment coefficient (EC) has been determined to derive the degree of heavy metal accumulation by plant species collected by *in-situ* and *ex-situ* method (Kisku *et al* 2000).

$$EC = \frac{\text{Concentration of metal in plants}}{\text{Concentration of metal at contaminated site}}$$

## RESULTS AND DISCUSSION

Elemental analyses of the eight soil samples collected from different industrial sites revealed varying concentrations of heavy metal contents (Table 1). Apart from HZL, soils of Govada sugars, Pharma city and Rain CII carbon also found with higher concentrations of Arsenic and Chromium. Among the tested samples, soils of both HZL and Coramandal Fertilizers contained highest concentrations of Zinc. Overall, among the eight different soil samples, HZL soil sample reported with higher concentrations of all the six metals tested for. The range of metal concentrations (in ppm) of HZL soil samples found in the following decreasing order: Zn=8030 > Pb = 960 > Cu=292 > Cd=221 > As=111 > Cr=108 (Fig 1&2). The physicochemical characteristics of soil play an important role in bioavailability of metals to plants in the environment. Soils of selected areas of HZL and garden soils were subjected to physicochemical analysis. The physicochemical characteristics like pH, CEC, organic matter etc., of the HZL soil varied when compared to the control soil (Table 2). These parameters known to influence the solubility, in turn the availability of metals to plants (Cataldo and Wildung1978, Chaney *etal*., 2000).The pH of the contaminated soil was acidic in nature compared to control. Acidic nature of the HZL soil enhances the bioavailability of metals to plants growing in the area. As expected Electrical conductivity of HZL soil, which is the function of ions, was higher compared to control (Bose and Bhattacharya 2008).

Table1: Elemental analyses of soil samples collected from different industrial regions

| Sl.No. | TEST SOIL | AS (in ppm) | Cu (in ppm) | Pb (in ppm) | Zn (in ppm) | Cd (in ppm) | Cr (in ppm) |
|---|---|---|---|---|---|---|---|
| 1 | CONTROL (University grounds) | 60±0.01 | 78±0.03 | 37±0.63 | 75±0.51 | 2±0.42 | 34±0.21 |
| 2 | HZL | 111±0.31 | 292±0.68 | 6960±1.11 | 8030±2.42 | 221±0.42 | 111±0.87 |
| 3 | GOVADA SUGARS | 220 | 115 | 49 | 144 | 9 | 249 |
| 4 | PHARMACITY | 111 | 126 | 64 | 248 | 16 | 203 |
| 5 | CORMANDAL FERTILIZERS | 94 | 268 | 45 | 7168 | 5 | 9 |
| 6 | HPCL | 80 | 99 | 55 | 120 | 12 | 52 |
| 7 | ESSAR INDUSTRY | 104 | 116 | 57 | 96 | 19 | 52 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 8 | RAINCII CARBON | 123 | 133 | 42 | 79 | 12 | 6 |
| 9 | PARRY SUGAR | 126 | 120 | 42 | 76 | 12 | 51 |

As=Arsenic; Cu=copper; Pb=lead; Zn=zinc; Cd=cadmium; Cr= chromium

| Parameters | Control soil | HZL soil |
|---|---|---|
| Colour | Reddish Brown | Light Brown |
| Bulk Density(gm/cc) | 1.236 | 0.73 |
| pH | 7.86 | 6.38 |
| Electrical conductivity (mmhos) | 2.7 | 3.56 |
| Water Holding Capacity(%) | 26.146 | 22.203 |
| Organic Carbon(%) | 0.64 | 0.91 |
| Soil Humus(%) | 0.399 | 0.282 |
| Calcium (mg/gm) | 4.8 | 3.603 |
| Magnesium(mg/gm) | 0.328 | 0.167 |
| Available Phosphorous(%) | 0.0456 | 0.0106 |

Table2: Physicochemical characteristics of contaminated soil of HZL

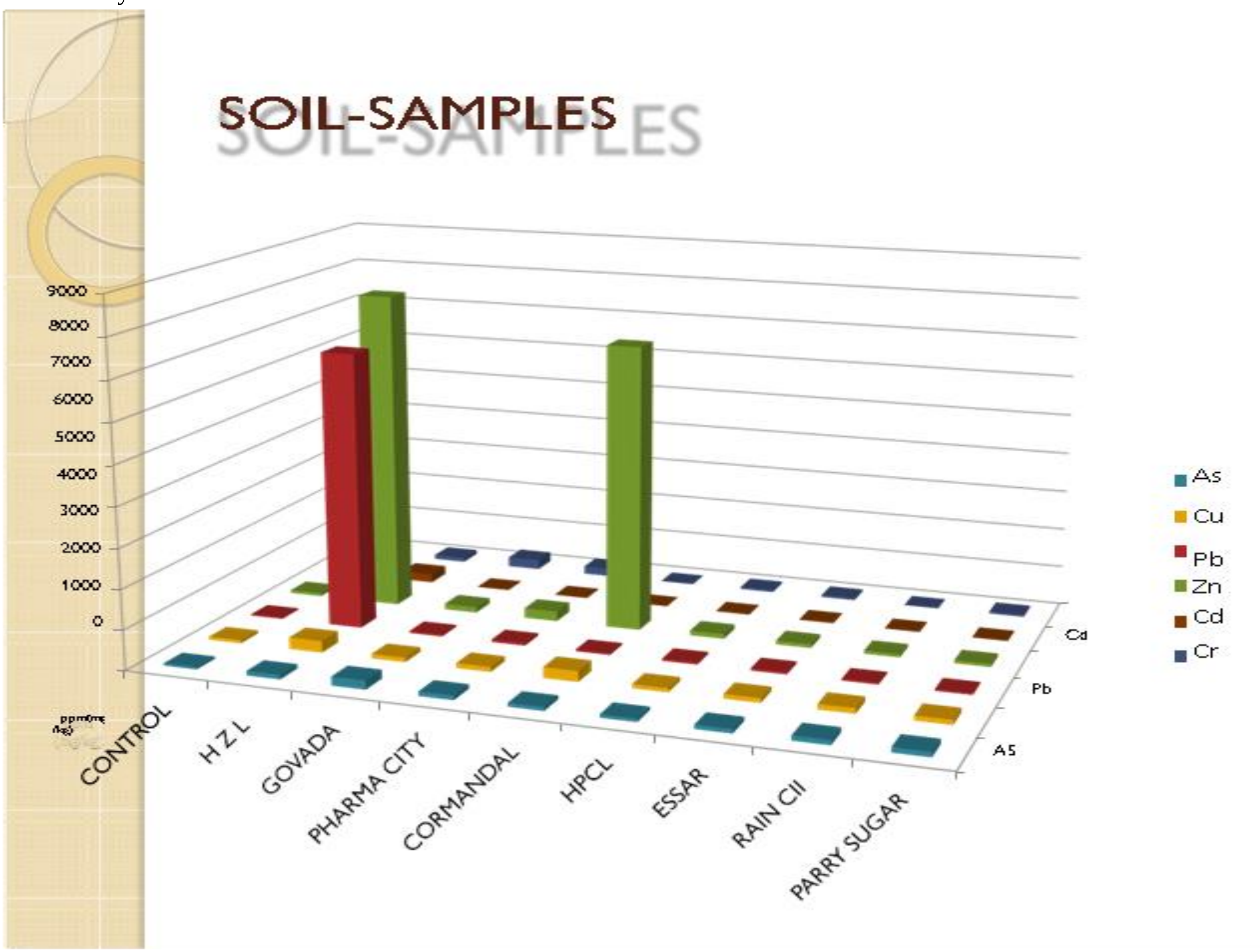


Fig.1 Elemental analysis of soil samples collected from different industrial sites

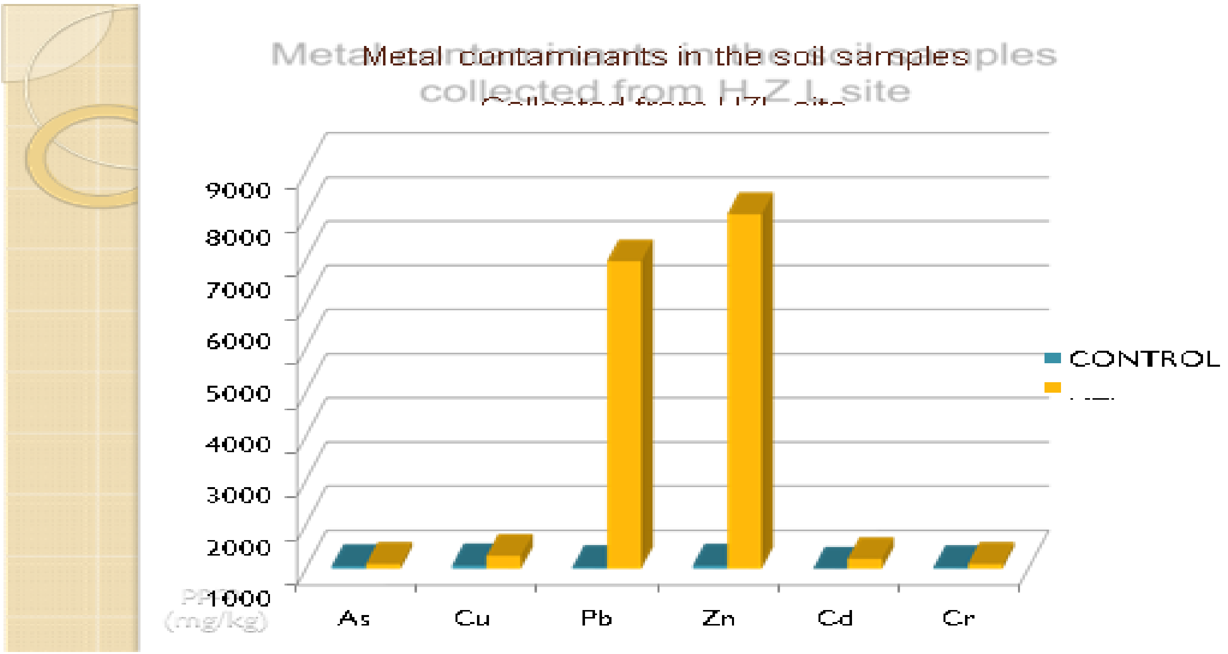


Fig2. Metal contaminants in HZL industrial site

METAL ACCUMULATION IN PLANTS

The range of metal accumulation was found to be varied in both *in-situ* and *ex-situ* weed species tested (Tables 3-4 and Fig.3). Enrichment coefficient (EC) has been used as an important criterion to assess the degree of accumulation of metals for both *in-situ* and *ex-situ* plants with respect to their concentration in the growing soil (Brown *et al.*, 1995 Kumar, *et al.* 1995, Ruskin, *et al.*, 1997. As suggested by many authors, higher the EC value is indicative of greater ability of a species as hyper accumulator of a respective metal. As is evidenced from the EC values *Cynodon dactylon, Alternanthera sessilsi* and *Datura stromonium* were found to be hyper accumulators for Arsenic metal while Lead and Zinc metals, *Alternanthera sessilis,Cynodon dactylon* and *Tridax procumbens* show to be the best hyper accumulators among the *in-situ* weeds tested. *Cynodon dactylon* exhibited better EC values followed by *Alternanthera sessilis* for cadmium metal. *Alternanthera sessilis* shown to exhibit highest EC values of all the *in-situ* weeds tested. Apart from the ten *in-situ* weeds, green house cultures were carried out with four different species viz., *Brassica nigra* , *Datura metel*, *Ipomea cornea* and *Pisum sativum* in the pots with the polluted soil. *Brassica nigra* was used as control. *Brassica nigra* was found to effective accumulator for lead, cadmium, zinc and copper metals (Reeves 2000). Analyses of *Datura metel* and *Ipomea cornea* revealed higher EC values for arsenic metal while *Ipomea cornea* and *Pisum sativum* for chromium metal. Overall, the data reveal that the efficacy of hyper accumulation of metals in *in-situ* weed species was in the following descending order: *Alternanthera sessilis* > *Cynodon dactylon*>*Tridax procumbens*>*Datura stramonium* > *Catheranthes roseus.* Among *ex-situ* plant species tested *Brassica nigra* lead the list followed by *Datura metel* > *Pisum sativum* > *Ipomia cornia* .

As is evident, *Alternanthera sessilis*, *Cynodon dactylon* and *Tridax procumbents* among *in-situ* species and *Brassica nigra* from greenhouse culture experiments exhibited better ability to accumulate lead, zinc, arsenic and cadmium metals. Several reports assent that EC > 1 is indicative of the special ability of a species to extract and transport metals from substrate to the plant tissues (Backer*etal* 1994; Wei*etal* 2002). The present findings suggest weeds growing naturally in the contaminated environment adapt better ability to accumulate metals to a higher degree in plant tissues as is evident from the analyses of *in-situ* visa vis *ex-situ* weed species.

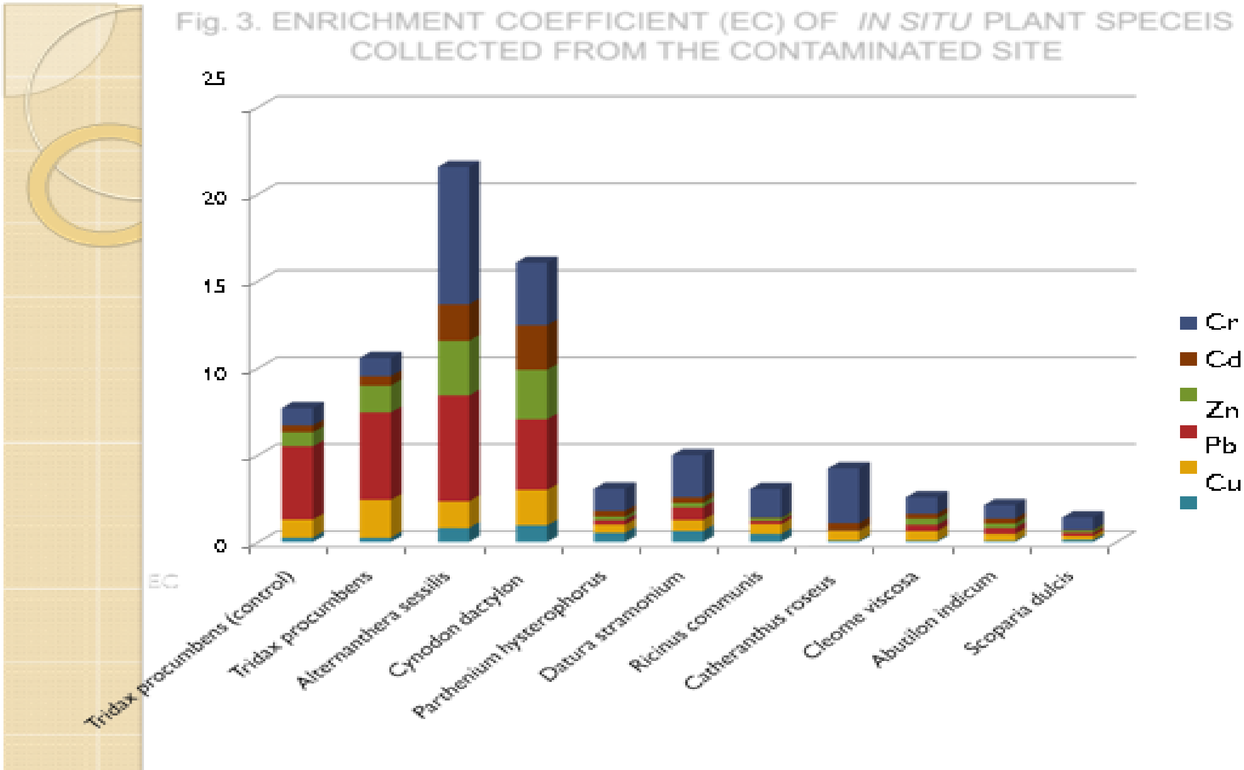


Table3: Enrichment Coefficient (EC) of *in-situ* plant species collected from contaminated HZL site

| TEST SPECIES | As (ppm) | Cu (ppm) | Pb (ppm) | Zn (ppm) | Cd (ppm) | Cr (ppm) |
|---|---|---|---|---|---|---|
| *Tridax procumbens* (control) | 0.26±0.14 | 1.03±0.23 | 4.21±1.03 | 0.8±0.77 | 0.4±0.02 | 1.0±0.21 |
| *Tridax procumbens* | 0.25±08 | 2.17±0.12 | 5.03±1.42 | 1.54±0.92 | 0.54±0.64 | 1.05±0.02 |
| *Alternanthera sessilis* | 0.8±0.54 | 1.54±0.21 | 6.08±0.98 | 3.14±1.34 | 2.1±0.23 | 7.9±1.21 |
| *Cynodon dactylon* | 0.95±0.06 | 2.04±0.65 | 4.06±0.04 | 2.85±0.08 | 2.56±0.023 | 3.6±0.15 |
| *Parthenium hysteroporous* | 0.52±0.06 | 0.47±0.03 | 0.26±0.01 | 0.2±0.02 | 0.33±0.01 | 1.28±0.41 |
| *Datura stramonium* | 0.63±0.09 | 0.63±0.02 | 0.73±0.32 | 0.26±0.01 | 0.32±0.06 | 2.42±0.02 |
| *Ricinus communis* | 0.46±0.1 | 0.56±0.01 | 0.19±0.04 | 0.16±0.02 | 0.03±0.01 | 1.64±0.01 |
| *Catheranthus roseus* | 0.08±0.02 | 0.55±0.04 | 0.04±0.03 | 0.03±0.02 | 0.39±0.13 | 3.14±0.21 |
| *Cleome viscosa* | 0.07±0.02 | 0.55±0.01 | 0.36±0.16 | 0.36±0.02 | 0.28±0.03 | 0.95±0.02 |
| *Abutilon indicum* | 0.06±0.04 | 0.4±0.022 | 0.34±0.06 | 0.26±0.01 | 0.28±0.12 | 0.78±0.21 |
| *Scoparia dulcis* | 0.126±0.11 | 0.23±0.43 | 0.17±0.02 | 0.14±0.01 | 0.03±0.01 | 0.71±0.02 |

Table4. ENRICHMENT COEFFICIENT (EC) OF *EX-SITU* PLANT SPECEIS GROWN IN THE CONTAMINATED (HZL ) SOILS

| | Test species | As (ppm) | Cu (ppm) | Pb (ppm) | Zn (ppm) | Cd (ppm) | Cr (ppm) |
|---|---|---|---|---|---|---|---|
| 1 | *Brassica nigra* (control) | 0.62±0.42 | 0.89±0.33 | 0.78±0.03 | 0.63±0.21 | 0.86±0.11 | 0.85±0.75 |
| 2 | *Brassica nigra* | 0.55±0.21 | 0.6±0.11 | 0.52±0.31 | 1.5±0.42 | 2.25±1.01 | 0.38±0.11 |
| 3 | *Datura metal* | 1.22±0.44 | 0.16±0.47 | 0.39±0.03 | 0.38±0.02 | 0.78±0.03 | 1.28±0.15 |
| 4 | *Ipomia cornia* | 1.05±0.04 | 0.1±0.34 | 0.33±0.02 | 0.3±0.68 | 0.81±0.31 | 1.0±.0.07 |
| 5 | *Pisum sativum* | 0.16±0.01 | 0.58±0.31 | 0.63±0.36 | 0.53±0.02 | 0.9±0.11 | 1.35±0.52 |

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