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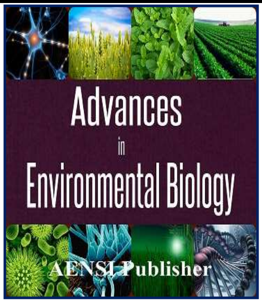


# Assessing airborne heavy metals pollution using *Calotropis procera* L. plants as biomonitors in Jeddah City, Kingdom of Saudi Arabia.

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**ABSTRACT**

This study was conducted to assess pollution with airborne heavy metals (Cd, Pb, Cr and Zn) in ambient air of Jeddah city, Kingdom of Saudi Arabia by using *Calotropis procera* L. plant spices as biological monitors growing abundance at the region. For this purpose, soil and plant leaves samples were collected from four different areas within city and analyzed to estimate the studied heavy metal levels. The study outcomes showed that heavy metals concentration means of Cd, Pb, Cr and Pb were significantly higher in soil than in plant leaves at all studied areas. Results, also indicated that out of the four examined areas, industrial area was the highest polluted area > road side > residential > control which has the lowest concentrations of all selected heavy metals either in soil or plant samples. The maximum concentration means of Cd, Pb, Cr and Zn in un washed plant leaves were (7.09, 31.8, 73.35 and 158.4) mg/kg of plant dry weight ,respectively. The maximum percentage of selected heavy metals could *C. procera* remove from their quantities in soils collected from the studied areas were as follows: (40.67 % of Cd ), (38.65% of Cr), (48.53% of Pb) and (36.50% of Zn). Based on the differences between heavy metal concentrations in washed and un washed leaves, it was concluded that there was an aerial heavy metals deposition at all examined areas at different proportions. Finally, it was recommended that *C. procera* plant can be used, efficiently as a bionidicator for heavy metal pollution biomonitoring at environmental polluted sites specially at arid land countries where it grows naturally and abundance.



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## INTRODUCTION

Pollution of soil, dust, water and foods by highly toxic heavy metals represents a great environmental concern, and continuous to receive particular attention around the world [37]. Heavy metals are non-biodegradable and tend to accumulate in the tissues of living organisms [41]. Airborne heavy metals, such as cadmium (Cd), lead (Pb), chromium (Cr) and zinc (Zn) are serious environmental air pollutants, particularly in areas with industrial activities and traffic density and on the other hand, they are classified among the most dangerous groups of anthropogenic environmental pollutants due to their toxicity and persistence in the environment [2,36,9,45]. The presence of these heavy metals in the atmosphere, soil and water even in traces can cause serious problems to all organisms, also heavy metal bioaccumulation in the food chain can be highly dangerous to human health [39]. Lead poisoning damages all important organ systems notably the nervous system [26]. Cd can cause kidney damage, impair skeletal and reproductive systems and other health problems [17]. All forms of chromium (trivalent Cr-III or hexavalent Cr-VI) measured together are called total chromium. Too much Cr-III can be toxic to plants and animals. Human activities such as chromite mining and ferrochrome manufacture can convert Cr-III into Cr-VI, which is also toxic and is known to cause cancer. Cr-VI can more easily move into the cells of plants, animals and micro-organisms, so it has a greater potential for toxicity. However, some species can store high amounts of chromium in roots and above-ground parts. These "hyperaccumulators" can be aquatic or land plants, [25]. Heavy metals emitted into the environment in different ways, i.e. transportation, industry, fossil fuels, agriculture and other human activities [5]. The most economical and reasonable method for monitoring the heavy metal levels in the atmosphere is using vegetation species,

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[43]. The basic criteria put by Markert [24] and Wittig [42] for the selection of a species as a biomonitor, were that it should be represented in large numbers all over the monitoring area, have a wide geographical range, should be able to differentiate between airborne and soil borne heavy metals, be easy to sample, inexpensive to sample and there should be no identification problems. Several studies reported that plants capture trace elements and can be used as biomonitors [23]. In the city of Thessaloniki (Greece), Sawidis *et al*. [35] studied air pollution with heavy metals using trees as biological indicators and reported that high levels of heavy metals came from vehicular emissions. In a study conducted by Pyatt [33] it was reported that heavy metal concentrations were found in the pine needles and in another study (2001) he also reported that *Acaccia retinoides* acts as effective bioaccumulators of heavy metals. Pantawat S. *et al*., [28] fount that the highest accumulation of chromium in *Cynodon dactylon* root was 94.59 mg/kg dry weight of plant under the effect of the treatment of 5 mg Cr/kg after 60 days of planting. The use of higher plant leaves as biomonitors of heavy metal pollution was increased in the terrestrial environment during the past few decades [4]. In Saudi Arabia, many environmental studies were conducted on wild plants and heavy metals in some areas, examples, date palm leaflets was used to monitor the distribution of airborne Pb, Zn, Cr, Ni, Li and other heavy metals in the city of Riyadh, Saudi Arabia [8]. Also Tulyan and Al-Farraj [40] used *C. procera* as a bio-indicators for Pb in Al-Riyadh city. Aldhaibani *et al.*, [1] found that Canola plant (*Brassica napus* L.) could remove amount of Pb ranged between 44 to 67 % from the Pb content of the polluted soil. In another study conducted by Prajapati S. [30], it was clearly indicated that *C. procera* L. plant can be used as biomonitor for As, Pb, Fe, V, Cd, Cr, Zn and Cu and he also found that the mean concentration of Cd, Cr, Pb and Zn were 3.9, 16.50, 2.14, and 33.53, respectively.

In Arid lands region, Saudi Arabia for instance, in addition to *Calotropis procera* several wild plants growing naturally in cities and around industrial areas or highways were used either ad bioindicators and boimonotors or as phytoremediators, some examples like: *Convolvolus sp.* , *Ochradus baccatus*, *Pergularia tomentosa*, *prosopis juliflora Rhiza stricta, as mentioned in* Al-Farraj and Al-Wabel [6] *and Malva parviflora, Datura stramonium*, *Citrullus colocynthis*, *Phragmites australis*, *Lycium shawii which were used for the* evaluation of phytoremediation potential of six wild plants for metal in a site polluted by industrial wastes: a field study in Riyadh, Saudi Arabia [18]. Alkateeb A. and Leilah A. [7] used some other wild plants growing in the Eastern Province of Saudi Arabia as bioindicators of heavy metals.

Zinc concentrations found in some studies either in urban, industrial or roadsides areas were as follows: Aksoy A. and Demirezen [3] found that the highest concentrations of Zn in washed plant leaves samples were recorded from the urban roadside (29.41 $mgkg^{-1}$) and from the industrial site (25.16 mg/kg) and the highest concentrations of Zn (92.64 μgg-1) was found in the associated soils samples from the urban roadside. In another study conducted by Alkateeb A. and leilah A. [7], it was found that the analysis of 10 wild plants species grown at Al-Jubail industrial area, Eastern of Saudi Arabia (the area with high intensive indusial activities ) accumulated concentrations of Zn ranged from 6.9 to 35.8 mg/kg .

In a study titled Heavy metals Accumulation of some plant Species Grown on Mining Area at Mahad AD' Dahab, Saudi Arabia, Al-Farraj and Al-Wabel [6] found that Zn concentrations in plant samples of *Convolvulus sp*. and its associated soil as 40.4 mg Zn /kg plant tissue and 92 mg Zn /kg of soil, respectively. For the Prosopis juliflora plant and its associated soil, they found 69.2 mg Zn /kg and 155 mg Zn/kg of plant and associated soils ,respectively. Zn concentrations in listed studies were lower than its concentrations usually found where Zn is a threat in places such as mines and smelters of the element or old sanitary land fields.

## MATERIAL AND METHODS

*Study area:*

sampling sites were located in and around of Jeddah city, Saudi Arabia. Jeddah is located at 20' 30" to 22' 30" on the western coast of Saudi Arabia on the Red Sea. It is the second largest city and the most significant commercial center in the Kingdom of Saudi Arabia.

The growth of the city over the last thirty years has been rapid and diverse, and continues to date. The population was 3,513,717 in 2010 and the number will increased to 4,542,930 in 2020 (CDSI, 2015). The climate in Jeddah is arid and the rainfall is less than 100 mm falling mainly during winter, with limited rainfall detected in summer. The temperature mean is 28°C, but the maximum temperature reaches to 40°C in all months of summer and the maximum temperature decreases to 18°C in winter. The relative humidity decreases to less then 15% in most months but it may reach to 100%. The blowing dust happened in more than 37 days/year and 2.7 days/year is a sand storm (PMEP data 1980-2010).

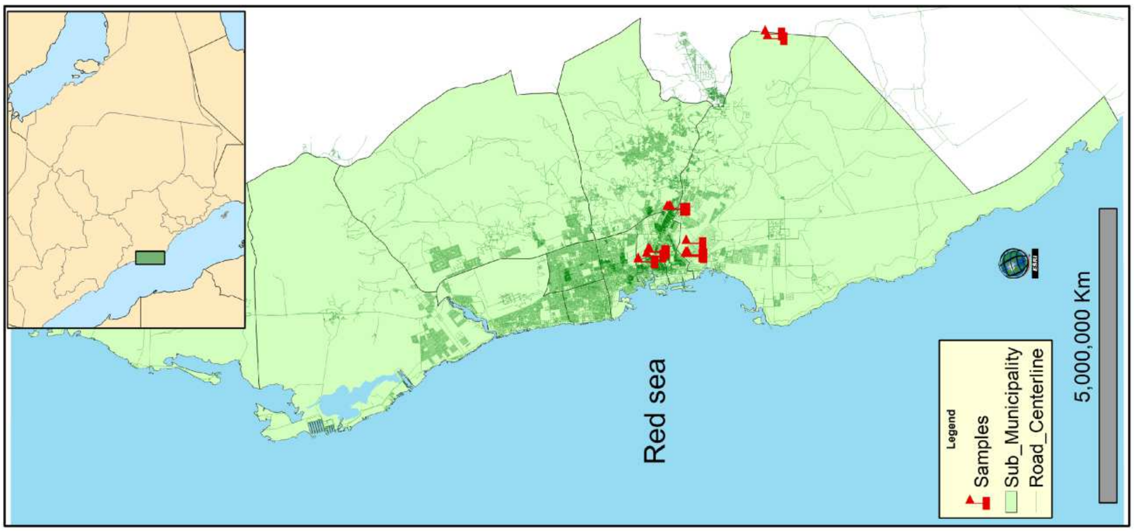


**Fig. 1:** Study area and samples locations on Jeddah Map.

*Samples collection:*

*Calotropis procera* (Aiton) WT Aiton. from Asclepiadaceae is a densely leafy large bush or a small tree up to 5m. high and grey-green waxy leaves and stems with ovate to obvate 10*15cm. [13]. The plant often branches at its base, which oozes a copious milky sap when cut. The inflorescence is a dense with greenish flower; corolla is white and pink/purple, and 2–3 cm in diameter. The fruit are follicle, grey-green, sub-globose to obliquely ovoid 8–12 cm long and contain hundreds of seeds. The roots are up to 4 m long and can form large tubers. Transverse section through the midrib shows an upper and lower, single-layered epidermis that is covered with a thick, striated cuticle (about 1 lm in thickness) [22].

*Calotropis procera* is adapted to high temperature (tropical) in arid and semiarid regions without irrigation, chemical fertilizers, pesticides or other agronomic practices [38]. It favors the habitats that receive 150–1,000 mm annual rainfall or less. The monthly annual temperature mean for the species' ranges from 20 to 30 C$^{\circ}$, and it is not frost tolerant [22]. It is distributed in tropical Africa and South West Asia, widespread species in nearly all the phytogeographical regions of Arabia Peninsula, especially, in edges of lowlands, wadis and raudhas [13], it has capable of surviving in a range of soil types, including sand dunes [16], alkaline and saline soils and prefers free-draining sandy soils, so that it could be one of the important species from the ecological aspects in arid and semiarid region.

All parts of the plant are reported to be toxic [11]. During the dry season in northern Australia, cattle are reported to graze calotropis extensively, without obvious harm [29]. It is used as a medicine plant [22]. Kumar *et al*., [21] reported around 50 of the medicinal properties for this plant. It has also been used to produce fibre [22], and has been suggested as suitable for bio-fuel production [29].

*Calotropis procera* which is growing abundantly in the examined arid land areas was used in this investigation as a biomonitor of airborne Cadmium (Cd), Lead (Pb), Chromium (Cr) and Zinc (Zn). *C. procera* plants were selected for this study because these plants are common plants at all areas all over Jeddah city and surroundings, in all seasons and can serve as biomonitors of heavy metal pollution. Five plant and soil samples were collected from different points in each area of the four environmentally different studied areas in Jeddah city during July 2014 as shown in Figure (1): (1) Industrial area, (2) Road side (along the high way, east Jeddah), (3) Residential area (Urban) and (4) Unpolluted control area (Rural area) as background about 30 km south east Jeddah. The plant samples were saved in brown paper bags and the 0-20 cm associated soil samples were saved in plastic bags and both were transferred to the laboratory. *C. procera* was selected because of its abundance during all seasons in all studied areas and also for its high air pollution tolerance index.

*Sample preparation:*

In the laboratory, Plant samples were divided into two groups. One was properly washed with running tab water for half minute/sample then with deionized water to remove dust particles and the other group remained un washed. All plant samples were dried at room temperature for 3 days then with oven drier at 70 $^{\circ}$c for 48 h. Fine powder of each plant sample was prepared by using electrical metal grinder. Surface soil (0-20 cm.) samples from each location were cleaned from strange materials and herbs then dried as plant samples and finally sieved through 2 mm. sieve. All samples were packed in labeled zip plastic bags and saved until analyzing.

*Soil samples Physical and Chemical analysis:*

All physical properties of the soils of the studied areas presented in (Table 1) were achieved in the soil laboratory in the faculty of Environment, Meteorology and Arid Land Agriculture, King Abdulaziz University, Saudi Arabia.

**Table 1:** Soil physical properties of the studied areas

| Location | pH | EC (mmos) | O.C % | T.O.C % | O.M % | Texture |
|---|---|---|---|---|---|---|
| Industrial | 6.84 | 5.03 | 1.08 | 1.44 | 2.49 | Sandy Loam |
| Road side | 7.24 | 2.2 | 0.44 | 0.58 | 1.00 | Loamy Sand |
| Residential | 7.08 | 12.77 | 0.52 | 0.69 | 1.20 | Sandy Loam |
| Control | 7.62 | 0.381 | 0.08 | 0.11 | 0.19 | Sand |

*Plant and soil samples chemical analysis:*

0.5 g. of each dried and powdered plant sample and soil sample was accurately weighed on an electronic balance and was transferred to 100 ml digestion flasks for digestion process to abstract the studied heavy metals as total concentrations. Then, in to each flask, 10 ml of a digestion mixture comprising of concentrated Perchloric acid ($HCLO_4$) and Nitric acid ($HNO_3$) in the ratio of (3:5 by volume) was added to each flask. The flasks were heated on hot plate till 1 mL remained at the bottom of the flasks with white color residue. This obtained volume was cooled, filtered, made up with deionized water to 50 mL in a volumetric flasks and finally, decanted in to plastic bottles. A blank was also run under similar conditions.

*Elemental analysis:*

The studied heavy metals, Cd, Pb, Cr and Zn concentrations were determined by inductively coupled plasma optical emission spectrometry (ICP-OES) and all necessary precautions were adopted to avoid any possible cross pollution according to AOAC guidelines, 1998. The objective of this study was to assess pollution with heavy metals (Cd, Pb, Cr and Zn) in ambient air of Jeddah city by using *C. procera* L. plant spices as biological monitors through the estimation of the concentrations of the selected heavy metals in soil and plant samples collected from 4 different areas in Jeddah city. The relationship between these heavy metal pollutants and the studies areas specially the industrial and roadside areas is that these areas are considered one of the most sources of Cd, Cr, Pb and Zn and these heavy metals affect on the life aspects either in these areas or in the clean areas like control area.

*Statistical Analysis:*

The obtained data were statistically analyzed according to the used design" Completely randomized Design" and the means were statistically compared using the Least Significant Difference (LSD) test at $p \leq 0.05$ after application the analysis of variance assumptions using SAS program [34].

*Results:*

*Heavy metal concentrations in plant and soil:*

All soil properties listed in table 1 were determined according to Pansu, M. and Gautheyrou, J. [27]. Data in Table (2) showed the analysis of variance (ANOVA) results and it revealed that there significant effects, at $p \leq 0.01$, of the studied polluted areas on the concentrations of Cd, Cr, Pb and Zn detected by the *Calotropis procera* plant leaves which used as bioindicator of airborne heavy metal pollution in Jeddah city.

**Table 2:** Analysis of Variance of Cd, Cr, Pb and Zn in *Calotropis procera* leaves under the effects of different areas in Jeddah city.

| Source of Variation | df | MS | | | |
|---|---|---|---|---|---|
| | | Cd | Cr | Pb | Zn |
| Treatments | 7 | 19.74** | 284.07** | 1667.06** | 6440.29** |
| Error | 16 | 0.003 | 0.005 | 16.76 | 13.68 |

** : Significant at $p \leq 0.01$

Concentration means of Cd, Cr, Pb and Zn in *C. procera* plant leaves and in soil samples collected from different locations in each of the four studied areas (Table 3). The statistical comparison of means using LSD test at $p \leq 0.05$ showed significant differences between heavy metal means in plant leaves under the effects of the studied areas and also showed that there were significant differences among the polluted areas regarding to the studied heavy metals.

**Table 3:** Means of Cd, Cr, Ni, Pb and Zn in *Calotropis procera* leaves and soil under the effects of different polluted areas and control in Jeddah city.

| Treatments | Means of heavy metal (mg/kg) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cd | | | Cr | | | Pb | | | Zn | | |
| | Un washed | Washed | Soil | Un washed | Washed | Soil | Un washed | Washed | Soil | Un washed | Washed | Soil |
| Industrial | $7.09^{a}$ | $4.38^{c}$ | $10.77^{a}$ | $31.8^{a}$ | $17.51^{c}$ | $45.3^{a}$ | $73.35^{a}$ | $57.37^{b}$ | $118.21^{a}$ | $158.4^{a}$ | $67.38^{c}$ | $347.02^{a}$ |
| Road side | $5.19^{b}$ | $2.17^{e}$ | $6.38^{b}$ | $20.33^{b}$ | $12.00^{e}$ | $38.50^{b}$ | $42.20^{c}$ | $23.07^{d}$ | $98.44^{b}$ | $78.07^{b}$ | $47.27^{e}$ | $142.58^{b}$ |
| Residential | $3.33^{d}$ | $0.85^{f}$ | $3.51^{c}$ | $16.77^{d}$ | $7.35^{f}$ | $29.20^{c}$ | $38.18^{c}$ | $17.88^{ed}$ | $76.41^{c}$ | $54.60^{d}$ | $35.50^{f}$ | $97.26^{c}$ |
| Control (background) | $0.12^{g}$ | $0.001^{h}$ | $0.08^{d}$ | $5.27^{g}$ | $1.29^{h}$ | $11.17^{d}$ | $12.53^{e}$ | $4.48^{f}$ | $21.38^{d}$ | $21.31^{g}$ | $8.17^{h}$ | $33.21^{d}$ |

* Means followed by the same letter (s) for each metal in washed, unwashed or soil are not significantly different according to LSD at $p \leq 0.05$.

*Heavy metals distribution in plant and soil samples of studied areas:*
*Plant leaf heavy metals contents:*
*Cd:*

Cd concentration in the unwashed leaves of the plants grown in the industrial area was significantly higher than the other plant Cd concentrations of washed leaves. The data (Table 3) showed that the unwashed leaves had Cd concentrations with significantly differences than the washed leaves. The Cd concentrations in the washed leaves of the plants grown in the control area was significantly the lowest values compared with the other treatments. Cd concentration in the plant leaves ranged from 7.09 mg/kg under the industrial area to 0.001 mg/kg in the washed leaves of the plants grown in the control area

*Cr:*

Calotropis *procera* plant absorbed around 17.5 mg Cr/kg of dried plant leaf in washed plant samples collected from the industrial area locations and Cr concentration mean was 31.8 mg /kg of dried plant leaf in unwashed plant samples from the same area. The minimum concentration mean of Cr was found in the plant samples collected from the control locations as 5.27 mg /kg in unwashed control plant leaf samples and of 1.29 mg/kg in the control washed plant samples. The industrial area contained the maximum Cr level followed by road side > residential > background area which has the lowest concentrations means.

*Pb:*

For plant samples, elemental analysis results showed (73.35, 42.20, 38.18 and 12.53) mg/kg of unwashed dried plant tissues collected from industrial area, road side area, residential area and control, respectively. The washed plant samples showed less Pb concentrations than unwashed samples, the maximum Pb concentration mean was 57.37 mg/kg in the industrial washed plant samples and the minimum was of 4.48 mg/kg in control washed plant samples. Pb levels in plant samples were under the toxicity limits reported by [15].

*Zn:*

Out of the four studied heavy metals in this investigation, Zn was the highest in all studied areas. The statistical comparisons of means (Table 3) using LSD test between the treatments at $p \leq 0.05$ showed significant differences between Zn concentration means in the studied areas. The maximum Zn concentration mean was found of 158.4 mg/kg for unwashed plant samples and represented about 45.7% of the soil Zn concentration in the industrial area but this ratio was of 18% for washed plant samples in the same area. The Zn minimum concentration means in the control samples were (21.31, 8.17 and 33.21) mg/kg for unwashed, washed and soil samples ,respectively. The ratio between the minimum Zn concentration means in unwashed to soil samples was about 64.16 % and it was for washed samples to soil samples about 24.6 %.

*Soil heavy metals contents:*
*Cd:*

Data showed in Table 3 showed that the total Cd concentration means in soil were ranged from 10.77 mg/kg in industrial area to 3.51 mg/kg in the residential area comparing with 0.08 mg/kg in the background soil samples. Cd concentration in soil in the industrial area was significantly higher than the other 3 soil Cd concentrations. Data in table 3 showed that the. The Cd concentrations in the soil of control area were significantly the lowest values compared with the other treatments.

*Cr:*

Significant differences were found between Cr concentration means at p≤0.05 in the soil under the effect of the different treatments. Total Cr concentration means ranged from 45.3 mg/kg of soil samples from the industrial area to 11.17 mg/kg of soil in the control samples and these concentrations are under the Cr toxic limits of 150 mg/kg in soils put by European Union Standards [15].

*Pb:*

Statistically, there were significant differences between Pb concentration means in industrial area and roadside but there were no significant differences between roadside and residential area (Table 3). Soil analysis showed higher levels of Pb than plant samples. Pb concentration means ranged from 118.21 mg/kg in soil samples collected from the industrial area to 21.38 mg/kg in the soil samples of control. Pb levels in soil samples were under the toxicity limits reported by [15].

*Zn:*

Data in table (3) showed that the total Zn concentration means in soil were ranged from 347.02 mg/kg in industrial area to 97.26 mg/kg in the residential area comparing with 33.21 mg/kg in the background soil. Zn concentration in soil of the industrial area was significantly higher than the other 3 soil Zn concentrations. Data in Table (3) also showed that the. The Zn concentrations in the soil of control area was significantly the lowest values compared with the other treatments.

*Efficiency of Calotropis procera as heavy metals phytoremediant:*

Data in Table (4) showed the percentages of heavy metals absorbed by *C. procera* plant from the soil determined in washed leaves. The maximum percentage of the studied heavy metals could *C. procera* remove of their quantities in soils were as follows: (40.67 % of Cd ), (38.65% of Cr), (48.53% of Pb) and (36.50% of Zn). Based on thisresults, *C. procera* plant can be used as a phytoremediant to clean up the polluted areas with heavy metals. According to Baker & Brooks, (1989) the *Calotropis procera* can't be considered as a hyperaccumulator for any of the studied heavy metals due to its inability of accumulation of concentrations higher than 100 mg/kg of Cd, higher than 1000 mg/kg of Pb and Cr or 10000 mg/kg of Zn in any of the examined areas.

**Table 4:** Heavy metal percentage (%) uptake by *Calotropis procera* from soil determined in washed leaves.

| Treatments | Cd<br>% | Cr<br>% | Pb<br>% | Zn<br>% |
|---|---|---|---|---|
| Industrial | 40.67 | 38.65 | 48.53 | 19.42 |
| Road side | 34.01 | 31.17 | 23.44 | 33.15 |
| Residential | 24.22 | 25.17 | 23.40 | 36.50 |
| Control | 0.13 | 11.59 | 18.38 | 24.60 |

*Bioaccumulation factor (BAF) calculation:*

By using heavy metal concentrations of washed plant samples and of soil samples included in table (3), heavy metal Bioaccumulation factor (BAF) which mathematically, given by equation ( BAC= Heavy metal concentration in leaf/heavy metal concentration in soil) was calculated and the results were listed in table (5). This factor is usually used to evaluate the plant ability for heavy metals uptake from the soil. The calculated value of BAF was less than 1 for each heavy metal in all examined areas.

**Table 5:** Bioaccumulation factor

| Treatments | Cd | Cr | Pb | Zn |
|---|---|---|---|---|
| Industrial | 0.4 | 0.4 | 0.5 | 0.2 |
| Road side | 0.3 | 0.3 | 0.2 | 0.3 |
| Residential | 0.2 | 0.3 | 0.2 | 0.4 |
| Control | 0.1 | 0.1 | 0.2 | 0.2 |

*Heavy metals deposited by air pollution deposition:*

Plant leaf washing process assesses in distinguishing between pollution caused by airborne and by soil borne contamination. Results included in table (4) showed that there was an aerial heavy metal deposition caused by air pollution on leaves and this aerial heavy metals were removed by leaf washing process. Results showed that Cd and Pb were most heavy metal deposited by atmospheric deposition on plant leaves in the residential and background areas but they were the lowest deposited on leaves in industrial area . The percent of reduction in heavy metal concentrations due to washing was found to be higher for Zn (57%) and Cr (44%) in industrial area plant samples than Cd and Pb of 38% and 22%, respectively. Soil of industrial area was the main source of the most quantity of Cd and Cr found in un washed plant leaf samples of that area.

**Advances in Environmental Biology**, 9(27) December 2015, Pages: 278-287

**Table 6:** Heavy metal percentage deposited by areal deposition

| Treatments | Cd | Cr | Pb | Zn |
|---|---|---|---|---|
| Industrial | 38 | 44 | 22 | 57 |
| Road side | 58 | 41 | 45 | 39 |
| Residential | 74 | 56 | 53 | 35 |
| Control | 99 | 76 | 64 | 62 |

*Discussion:*

Many heavy metals are generally added to the environment by aerial deposition from the roads with high density of traffic, industrial sources and other human activities. These pollutants reached to surrounding un industrial, residential and even to rural areas through the wind. The findings of this study (Table 3) showed significant differences between examined areas and between studied heavy metals and this could be attributed to the differences between those areas in terms of traffic and industrial activities. Out of the important outcomes gained by this study, it was found that the industrial, roadside, and to some extent, the residential areas were polluted with Cd, Cr, Pb and Zn heavy metals at different rates for each studied heavy metal. Another main result was that ,out of the four examined areas, industrial area was the highest polluted area > road side > residential > control which has the lowest concentrations of all studied heavy metals either in soil or plant samples and this order style was the same observation found by Aksoy *et.al.* [5] who found that the mean Pb, Cd and Zn concentrations in industrial sites were > roadside > urban and suburban sites, and significantly higher than in rural sites. Higher pollution in industrial than roadsides area can be attributed to the industrial activities, traffic and goods transportation within it, and to its exposure to pollutants from surrounding highways and also to its location toward the prevailing wind in Jeddah city. Traffic density in Jeddah city is one of the major causes of heavy metal pollution and due to this reason, the high heavy metal levels in the roadside and residential soils and plants were found and this finding was in agreement with Kadi, M.W. [20] who reported that increasing industrialization, urbanization, and vehicular traffic in Jeddah City could increase levels of heavy metals in air and soil, which leads to a high pollution. From the view of plant phytotoxicity, the results showed 4.38 mg Cd /kg, 17.51 mg Cr/kg, 57.37 mg Pb/kg and 67.38 mg Zn/kg as a maximum concentration and according to Kabata Pendias and Pendias [19], who put the concentration values of 5-30 mg/kg for Cd, 70–400 mg/kg for Zn, 75–100 mg/kg for Cr and 30-300 mg/kg for Pb. Cd and Zn approached the phytotoxic limit, Cr was lower than the phytotoxic limit and Pb was within the phytotoxic limit. Although Cd, Pb and Zn were in the range of phytotoxicity for the plants, *C. procera* plant was surviving healthy and in a high abundance within and around the studied areas and this means: it is heavy metals tolerant plant, it is a good option for heavy metals phytoremediation. According to the basic criteria put by Markert [24] and Wittig [42]for the selection of a species as a biomonitor, this study results showed that *C. procera* embodied all these criteria and it can be used as a useful a biomonitor for each of the metals Cd, Cr, Pb and Zn and because it is possible to measure the differences between aerial depositions and root uptakes as presented in Table 4 which indicated the percentage of each heavy metal quantity absorbed through the root. This finding was confirmed by the findings obtained by Al-Shayeb *et al*. [8] and Aksoy and Ozturk [4].

For Zn, this study findings were in the agreement with those results found by many reaearchers such Aksoy A. and Demirezen [3] and like Alkateeb A. and leilah A. [7] and Al-Farraj and Al-Wabel [6] in the arid arias, Saudi Arabia in this case.

Results listed in table (5) showed the BAFs values of all selected heavy metal in all investigated areas in this study and all values were less than 1. BAF can be used to estimate a plant's potential for phytoremediation purpose after Yoon *et al*. [44]. The data in table (6) showed the ratio between heavy metal concentrations in washed to un washed leaves samples reflects the effect of direct atmospheric contamination. Washing leaves significantly reduced the studied heavy metals concentrations in different rates for each heavy metal. For Cd, the reduction percentage was ranged from 38% in industrial area to 99% in control samples. This means that most of Cd in the control samples caused by aerial adsorption on leaves not by soil absorption. It is also clear that Cd, Cr, Pb and Zn deposition percentages in all samples collected from the clean area " control" were the highest for each heavy metals comparing with other polluted areas, and this is true scientifically and logically because no pollution sources area. Finally, this investigation is original and makes a distinct and significant contribution to the knowledge base specially, in this arid areas where data about the role of the natural plants in the field of airborne heavy metals biomonitoring are rare.

*Conclusion:*

These results indicated that the plant *C.procera* was a good bioindicator and can be used in air pollution monitoring studies in the polluted areas like industrial areas and roadsides where traffic density and therefore , it can be used as bioremediator for removing the heavy metal toxicity in these arid areas of Saudi Arabia where it grows naturally and abundance in the arid region. Overall the results of this study showed that all studied polluted areas were suffering of heavy metals pollution and significant differences between the examined areas were found. The aerial pollution deposition was significantly increased the levels of each heavy metal detected by soil and plant leaf and this was observed based on the differences of heavy metals in un washed to washed leaves samples. However, based on this study results, this plant can't be used as a hyperacommulater for Cd, Pb, Cr or Zn. Although *C. procera*, in this study showed a high ability for heavy metals tolerance, it was recommended that this plant must be not used for animal feeding or in a medicinal purposes in and around Jeddah City. From the view of Economic, *C. procera* can be used as a garden plant and in green belts around the roadsides and industrial areas, therefore, it is important to be protected as a part of the natural ecosystem in the arid and semiarid regions.

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