# A Quantitative Assessment of Inhalable Particulate Matter Pollution in Metropolitan Karachi

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**Summary:** Solid pollutants at four different sites at Karachi were collected by dry deposition for a month. Water soluble portions were analysed for arsenic, cadmium, copper, manganese, nickel, lead, antimony, zinc, sodium, potassium, ammonium, chloride, nitrate, phosphate and sulphate. The probable sources of emission of these elements and their correlation with each other is discussed.

## Introduction

The removal of the trace constituents under dry or wet weather conditions from the atmosphere to the earth surface is important in view of many aspects extremely divergent in nature. Their concentration if permitted to increase unchecked by a sink mechanism would be enormous [1]. These trace constituents depending on their nature could be hazardous to plants and animals [2-4] but could be a source of nutrients when present in the soil and surface waters [5,6]. Their presence can also influence the precipitation chemistry [7-9] and man made materials [7-10]. In addition, dry deposition is of great importance concerning the effects on dynamics of air pollutant concentrations and their mass balances [11].

Karachi (Lat:24°.52' N, Long:67°E) is located at the extreme southern tip of the semi arid zone of Sind. It is also a sea shore and a busy port encountering both the sea and the land breeze periodically. It is a heavily populated cosmpolitan, where atmosphere is constantly polluted by the industrial, domestic and urban pollution sources in addition to the materials of oceanic and anthropogenic origin. Since it seldom rains here, the dry removal of major and trace elements to the ground would be largely, the sink mechanism. All these factors make the study of the removal of particulates from the atmosphere of Karachi an attractive preposition.

The aim of the present work is to provide basic information on the removal of fifteen elements by dry deposition to earth's surface at Karachi in order to evaluate their correlation with the emission sources and also partly to determine

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the quality of surface water and earth's surface here.

*Sampling and Analysis*

The sampling was conducted at four different sites namely SITE, SADDAR, PECHS and KARACHI UNIVERSITY.

The SITE area houses a large number of industries of Karachi: SADDAR is the city centre, commercial area and has a very heavy automobile traffic; PECHS is largely a residential area, which contains some commercial centres; Karachi University, though located at the outskirts of the city, is surrounded by many ever expanding housing projects and resultant small scale business centres.

**Experimental**

The samples were collected by gravitational dust sampling method [12,13] for 28 days (5.12.1986 - 2.1.1987) in 8 inch diameter polyethylene containers prewashed with 3% nitric acid and deionized water. The deposition was divided into water soluble and insoluble components. The water soluble fraction was analysed for various cations and anions. The sodium and potassium were analysed by flame photometry, while arsenic, antimony, copper, cadmium, iron, lead, manganese, nickel and zinc were analysed by atomic absorption spectrometry. $NH4^+$, $Cl^-$ and $NO^-_3$ were determined spectrophotometrically (after complexing with Nessler's reagent, mercuric thiocynate chloride and brucine sulphate respectively) and sulphate was analysed as barium sulphate [14-17].

**Results and Discussion**

The probable contribution to the particulate matter at Karachi arises mainly from sea sprays, solid waste disposals and their incinerations, fuel combustion (coal, oil and gas), industrial effluents, soil dusts due to strong ground turbulence by wind, poor sanitation and locomotive exhausts particularly smoke due to poor maintenance of vehicles. In addition to all these emission sources, dry weather conditions lead to extensive accumulation of pollutants in the atmosphere especially when the only mechanism for the removal of pollutants is dry deposition by turbulent diffusion and gravitational sedimentation, as it seldom rains in Karachi.

Table 1 summarizes the total deposition obtained from each collection site as mg per square meter per day.

Table 1: Average total deposition (mg m-2 d-1)

| | Total deposition | Water soluble | Water insoluble |
|---|---|---|---|
| SITE | 1560 | 109 | 1452 |
| SADDAR | 2198 | 246 | 1952 |
| PECHS | 480 | 197 | 282 |
| KARACHI UNIVERSITY | 400 | 293 | 103 |

It is evident from the table that the mass of dry deposition is fairly indicative of the emission sources of particulate matter and wind velocities. The highest deposition levels are found at SADDAR where smoke and automobile exhaust are present in higher amounts. Apparently in this region the wind velocity is low due to tall buildings, consequently the particulates are not dispersed easily resulting in their accumulation in high concentration. In SITE, smoke, dust and industrial effluents are present in high amounts but since the area has a few tall structures and is close to sea, continuous breeze disperses the particulates. PECHS is relatively a lesser congested residential area and the industries in the vicinity are scarce. Thus, the contributions to the particulate concentration by traffic and industrial sources are low. The KARACHI UNIVERSITY area is open and exposed to strong breeze, as a result the particulate concentration is lowest here.

We shall now discuss various water soluble pollutants, their relative concentrations, possible sources of emission and their correlation with each other. Related data is given in Figure 1 and Table 2 and 3.

The pH shows that the nature of the soluble fraction is basic. High levels for alkalinity and hardness suggest a high percentage of basic components. Figure 1 shows variation in the concentration of pollutants at different sampling sites. The homogeneity in concentration of $Na^+$, $K^+$ and $Cl^-$ from site to site is indicative of their marine origin, as wind driven sea salts have a widely homogeneous distribution [18,19] in areas remote from sea coast. The concentration of Mn, Cu and Zn fluctuates at all sampling sites. Similarly heterogeneous distribution of other elements such

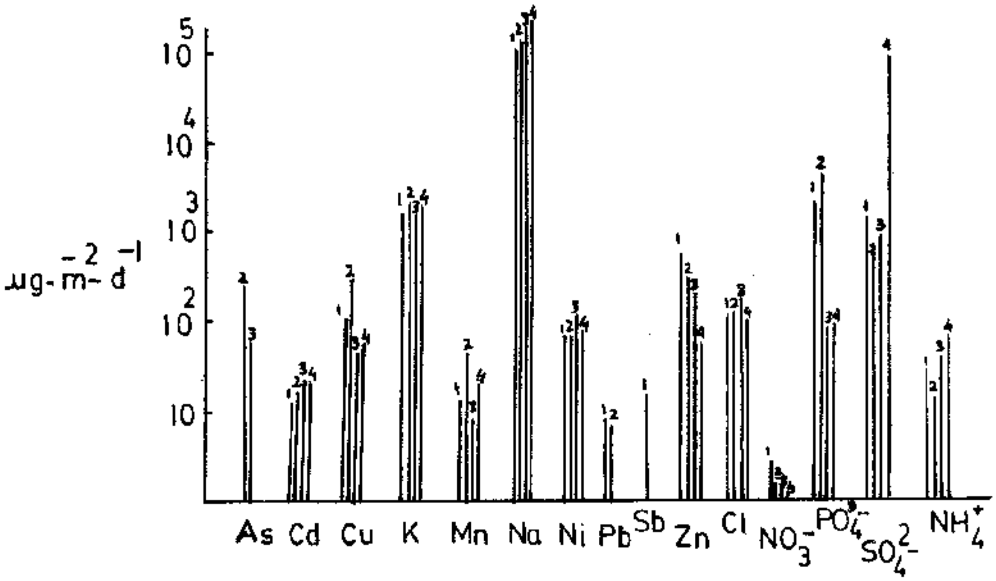


Fig.1: Average deposition of various elements at different sites 1. SITE; 2. SADDER; 3. PECHS; 4. Karachi University.

Table 2:Average per day levels of soluble pollutants

| | | | |
|---|---|---|---|
| pH | | 7.6 | |
| Alklinity | | 974 | $\mu$eq. m$^{-2}$ d$^{-1}$ CaCO$_3$ |
| Hardness | (EDTA) | 1347 | $\mu$eq. m$^{-2}$ d$^{-1}$ CaCO$_3$ |
| As | | 259 | $\mu$g m$^{-2}$ d$^{-1}$ |
| Cd | | 54 | " |
| Cu | | 390 | " |
| Mn | | 70 | " |
| Ni | | 330 | " |
| Pb | | 25 | " |
| Sb | | 1.3 | " |
| Zn | | 6713 | " |
| Na | | 146200 | " |
| K | | 2860 | " |
| $NH_4^+$ | | 60 | " |
| $Cl^-$ | | 182 | |
| $NO_3^-$ | | 78 | |
| $PO_4^{3-}$ | | 58609 | " |
| $SO_4^{2-}$ | | 5900 | " |

as As, Pb, Cd, Cu, $SO_4^{2-}$, $PO_4^{3-}$, and $NO_3^-$ represents their anthropo- genic origin [18,19].

The correlation matrix is given Table 3. It is surprising that correlation factor 'r' is low between $K^+$ and other marine constituents [20-23] which has also been observed by Parekh *et al.* [19]. A good correlation exists between $K^+$ and $PO_4^{3-}$ which is suggestive of their common source. $K^+$ is also highly correlated with the elements of anthropogenic and soil origin, like As, Cu, Mn, Cd etc. One may conclude that $K^+$ is also emitted from sources other than marine. Crustal [24-26] and anthropogenic sources of $K^+$ has been reported [26]. Cooper [27] indicated the release of $K^+$ especially from combustion of wood.

Manganese was found in all the samples. It is considered as an element of crustal origin [19,20,26,28]. However its concentration was highest in SADDAR samples. This very fact and the correlation of Mn with $K^+$, Cu and As suggests, the sources of Mn other than the crustal ones. Mn is usually used in steel alloys and soil conditioners [25].

Arsenic emissions to the atmosphere has been assigned to natural [29] or anthropogenic [30-32] sources. Its association in high concentration with coal combustion has been found [32-34]. Arsenic was detected only in samples at SADDAR and PECHS which corresponds to its emission from coal combustion at these locations.

The concentration of Cu at SADDAR is noticeable. It is found to be a minor component of fuel oil combustion [35].

Refuse incinerations result in the emission of large quantities of many elements such as Cd, Pb, Sb, Zn and $Cl^-$ [19,25,36-39] which indicates the possible sources of these elements at Karachi city. Furthermore, the correlation of As, Cd, Cu, $K^+$,

Table 3. Correlation matrix between various elements.

| | As | Cd | Cu | Mn | Ni | Pb | Sb | Zn | $PO_4^{3-}$ | $SO_4^{2-}$ | $Cl^-$ | $K^+$ | $Na^+$ | $NH_4^+$ | $NO_3^-$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| As | 1 | | | | | | | | | | | | | | |
| Cd | 0.85 | 1 | | | | | | | | | | | | | |
| Cu | 0.88 | 0. 87 | 1 | | | | | | | | | | | | |
| Mn | 0.59 | 0.25 | 0.57 | 1 | | | | | | | | | | | |
| Ni | 0.29 | 0.23 | -0.71 | -0. 50 | 1 | | | | | | | | | | |
| Pb | 0.34 | 0.27 | 0.13 | 0.26 | 0. 56 | 1 | | | | | | | | | |
| Sb | 0.97 | 0.80 | -0.35 | -0.44 | -0.41 | 0.21 | 1 | | | | | | | | |
| Zn | -0.67 | -0.60 | -0.41 | -0.14 | 0.74 | -0.24 | -0.14 | 1 | | | | | | | |
| $PO_4^{3}$ | 0.83 | 0.27 | 0. 80 | -0. 90 | -0.9 | 0.58 | 0.03 | 0.08 | 1 | | | | | | |
| $SO_4^{2-}$ | -0.58 | -0.20 | -0.33 | -0. 01 | 0.27 | -0.36 | 0.05 | -0.40 | 0.65 | 1 | | | | | |
| $Cl^-$ | 0.20 | 0.15 | -0.23 | -0.37 | 0.75 | -0.15 | -0.17 | - 0.80 | - 0.28 | -0.83 | 1 | | | | |
| K+ | 0.90 | 0.63 | 0.93 | -0.79 | 0.30 | 0.36 | -0.33 | -0.48 | -0.91 | -0.18 | -0.29 | 1 | | | |
| Na | 0.48 | 0.13 | 0.23 | -0. 84 | 0.32 | 0.14 | 0.04 | -0.97 | -0.19 | -0.99 | 0.86 | 0.07 | 1 | | |
| $NH_4^+$ | -0.75 | -0.04 | -0.83 | -0. 39 | 0.49 | -0.58 | -0.27 | 0.73 | -0.83 | 0.71 | 0.20 | 0.60 | -0. 67 | 1 | |
| $NO_3^-$ | -0.23 | -0.87 | 0.12 | -0.42 | 0.49 | 0.49 | 0.87 | - 0.27 | 0.19 | -0.12 | - 0.10 | -0.24 | 0.17 | -0.46 | 1 |

etc., is suggestive of deposition of these elements on the earth's surface from different emission sources and recycling in the ambient air with the soil dust due to ground wind turbulence. This point is also supported by correlations of these elements with Mn.

Ni was found in all the analysed samples. Unusually the Ni emissions are accounted by oil combustion [40,41]. Although oil refinery and oil fired plants are farther away from the present sampling stations, its presence may be explained if we consider the domestic use of oil as a fuel in addition to coal, gas and wood. Furthermore, Ni also finds its use as a catalyst in vegetable fat industries in Pakistan.

Sulphate is correlated in inverse sense with all the other elements except $NH_4^+$. The concentration of sodium is very high and at present we cannot account a source other than marine ones.

## Conclusion

From the preceding discussion it can be concluded that the particulate load of Karachi atmosphere originates from three sources. The two natural sources are the sea and adjoining arid zone of southern Sind, from where the pollutants are blown to Karachi by the sea and land breeze. The third source is human urban activities which include automobile exhausts, combustion, industries etc. Lack of rain would render the atmosphere highly polluted and dry precipitation is the only source of removal of the particulates from the air.

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