A Study of Cadmium Concentration, Its Transport and Distribution with Distance in the Jhalana Dungari Area, Jaipur

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Extensive quarrying activities in the Jhalana Dungari area of Jaipur are going on for over 25 years. Greenokite mineral (CdS) present in the area results in high concentration of Cd in the soil as well as in the water of the area. This paper presents the results of analysis of soil, rock and water samples for determining concentration of Cd, its transport and distribution with distance for the quarrying area. The findings reveal that in water samples the values are between 0.04–0.10 mg/L, which are considerably higher than the prescribed limits of WHO and US standards. Soil samples have Cd in varying concentration ranging from 0.40–1.50 mg/L. It has been found that Cd is distributed throughout the hill, but the concentration is higher around 20 metres from the base.

INTRODUCTION

Cadmium is regarded as one of the most toxic elements in the environment. Its persistence in the environment, rapid uptake and accumulation by food chain crops contributes to its potential environmental hazards. It is widely distributed over the earth's surface. Cadmium is not found in pure state in nature[1]. Cadmium occurs together with zinc in nature, the ratio[2] being generally 1 : 100–1 : 1000. The major classes of products where cadmium is present as an impurity are non-ferrous metals (zinc, lead and copper), iron and steel, fossil fuels (coal oil, peat and wood), cement and phosphate fertilisers[3].

Many studies have attempted to establish the average daily Cd intake resulting from foods. In general, these studies show that the average daily diet for non-smokers living in un-contaminated areas is at present at the low end of the range of 10 to 25 μg of Cd[4–6]. The human exposure resulting from the disposal of cadmium-containing products by incineration is even less and is generally considered insignificant[7, 8].

Cadmium is a non-essential element and highly toxic to human being and several other organisms. Acute and chronic poisoning is reported to occur among the industrial workers. Chronic poisoning may occur in occupationally non-exposed persons due to prolonged exposure to a low concentration of cadmium. In acute cases of cadmium poisoning, gastroenteric distress, pain, prostration, pneumonitis and pulmonary oedema may occur. In severe cases liver injury and convulsions have been reported[9]. In long term low level exposure the kidney is regarded as the critical organ and it has been estimated that renal dysfunction may appear when the Cd concentration in the renal cortex is around 200 mg/kg wet weight[10].

Heavy metal pollution due to mining and smelting is well known. Ferruginous quartzite rocks are present in Jhalana Dungari area, Jaipur. Greenokite mineral (CdS) can always be suspected in such rocks. A survey of the area could reveal no other possible source dumping cadmium into the environment. It is suspected that the extensive quarrying activity in the ferruginous quartzite rocks, to serve the stone requirment for construction activity in the fast growing city of Jaipur, could be a possible source of pollution.

The aim of this study, is firstly to analyse crushed rock samples from the different parts of the rock to pinpoint the source of pollution and secondly to analyse water and soil samples at different areas to judge the transport and distribution of cadmium.

EXPERIMENTAL

Method used in the present investigation was atomic absorption spectrophotometry (AAS). The Pye Unicam SP9 Series Atomic Absorption Spectrophotometer is a single beam, ratio measuring instrument. All versions can be fitted with the SP9 computer[11].

Sampling: All water samples (surface water, tube well water and open tank stored water) were collected from Jhalana Dungari Area, Jaipur. The samples were collected in non-metallic equipment (polyethylene bottles) to ensure that they may not get contaminated with heavy metals from the sampling and storage equipment[12]. In order to determine the concentration of cadmium in soil samples the entire area of study was divided into 6 zones. Zones 4th, 5th, and 6th were further subdivided into 4, 7 and 3 parts respectively and these were named series. Zones 4th, 5th and 6th were selected for detailed study as they were close to the populated area and the variation in concentration of cadmium was important considering their harmful effect on human beings. Similarly, to find out variation in concentration with height, we collected rock samples at 5 metre distances.

Processing of Samples: Water samples were filtered to make them free from turbidity and organic materials. They required no processing and analysed as such. Soil samples were dried. Cadmium in soil was determined by heating 10 g soil with 50 mL of 5 M HCl. The insoluble residue was filtered and filtrate was heated to dryness and final volume was adjusted to 100 mL with deionized water. The water and the soil samples were aspirated directly into the instrument.

RESULTS AND DISCUSSION

The mean, median and mode values calculated for water, soil and rock samples are presented in Table-1 and Fig. 1. The terms 'Mean', 'Median' and 'Mode' are explained below:

Mean	Average concentration
Median	Concentration found in most samples
Mode	Maximum concentration in any sample

TABLE-1
CONCENTRATION OF CADMIUM IN WATER, SOIL AND ROCK SAMPLES*

	Total No. of samples analyzed	Median	Mode	Range	No. of detectable samples	Mean
Water	20	0.04	0.10	0.04–0.10	10	0.029
Zone-1	45	0.65	1.20	0.40–1.20	45	0.721
Zone-2	45	0.65	1.20	0.40–1.20	45	0.706
Zone-3	45	0.65	1.50	0.40–1.50	45	0.814
Zone-4	45	0.65	1.20	0.40–1.20	45	0.721
Zone-5	75	0.40	0.65	0.40–0.65	75	0.456
Zone-6	45	0.40	0.65	0.40–0.65	45	0.450
Rocks	24	0.65	1.50	0.40–1.50	24	0.723

*All values are in mg/L.

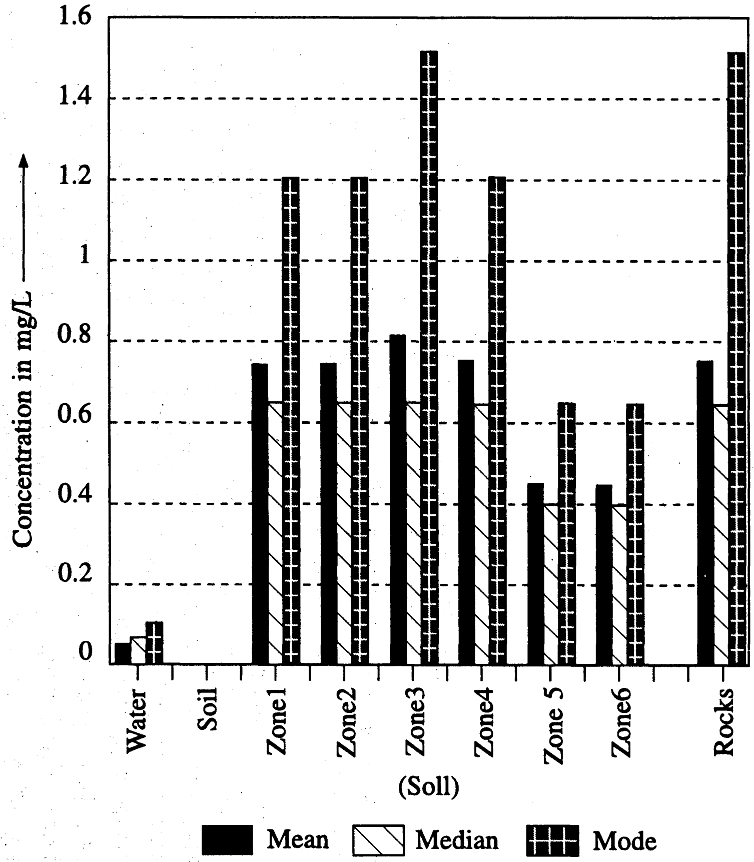

Fig. 1 Concentration of Cd in water, soll and rock samples

Water Analysis: A perusal of Table-1 shows that only 50% water samples have cadmium in varying concentration ranging from 0.040–0.10 mg/L. The remaining 50% samples which did not have detectable amounts of cadmium were collected from tubewells used by population of the area. However, cadmium contamination was in water samples collected from open tanks. It could, therefore, harm cattle but fortunately the population using tubewell water would be safe from use of drinking tubewell water. The mean, median and mode values calculated for Cd in water were in the following ranges

Mean = 0.029 mg/L

Median = 0.04 mg/L

Mode = 0.10 mg/L

These values are higher than the prescribed limit of WHO which is 0.005 mg/L and the US standard which is 0.01 mg/L. It is, therefore, necessary to treat this water before it is allowed for consumption by animals or human beings.

Analysis of Soil and Rock Samples: A perusal of Table-1 shows that cadmium is distributed throughout the hill. The concentration of cadmium varies from 0.40–1.50 mg/L. Most of the samples in zones 1st to 4th have concentration 0.65 mg/L through samples with minimum of 0.40 mg/L cadmium concentration to a maximum of 1.2 mg/L or 1.5 mg/L are also present. Further, cadmium concentration is not high in zones 5th and 6th and it varies within a short range of 0.40–0.65 mg/L. Most of the samples in these zones show minimum concentration of 0.40 mg/L found in the six zones of present study. Likewise, variations in concentration of rock samples at different heights have been observed. These variations are from 0.40–1.50 mg/L. All these values are quite high and could affect the population in different ways in several years.

Distribution: Distribution pattern of cadmium in zones 4th, 5th, 6th and with height are presented in Table-2 and Fig. 2.

TABLE-2
DISTRIBUTION OF CADMIUM IN SOIL AND ROCK SAMPLES*

Distance in meters	Zone-4	Zone-5	Zone-6	Height
At the root of the hill	0.65	0.40	0.40	0.40
5	0.65	0.40	0.40	0.40
10	0.40	0.40	0.40	0.40
15	0.40	0.15	0.15	0.65
20	0.40	0.15	0.15	1.20
25	0.40	0.15	0.15	0.65

*All values are in mg/L.

A study of variation in concentration of cadmium with distance in zones 4th, 5th and 6th indicates that the concentration of metal decreases to a constant value within the range of present investigations. These constant values are 0.40 mg/L

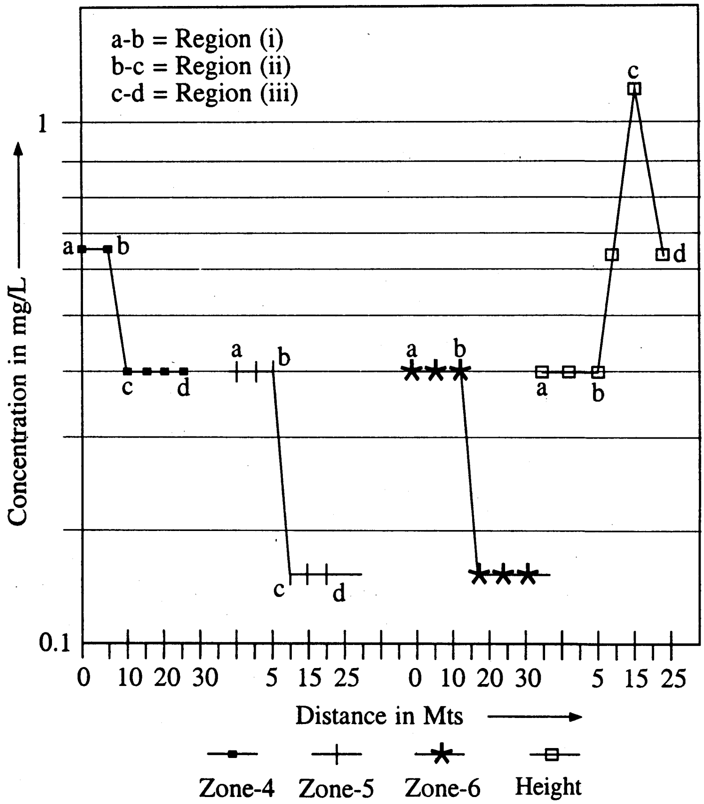

Fig. 2 Distribution of cadmium in soil and rock samples

for zone 4th but this is lower, *i.e.*, 0.15 mg/L, in zones 5th and 6th. Variation of concentration of cadmium in zones 4th, 5th and 6th follows the following pattern:

In Region I – Concentration of cadmium is constant with distance.

In Region II – Concentration of cadmium is decreasing with distance.

In Region III – Concentration of cadmium is constant with distance.

Cadmium concentration is also found to vary with the height of the rock. It is maximum at about 20 metres where it is 1.20–1.50 mg/L while it decreases beyond this height. The concentration is minimum at the base (0.40 mg/L). Variation of concentration of cadmium with height follows the following pattern,

In Region I – Concentration of cadmium is constant with distance.

In Region II – Concentration of cadmium is increasing with distance.

In Region III – Concentration of cadmium is decreasing with distance.

Transportation: A close examination of the map of the quarrying area shows that the hills under study extends from north to south and the southern area covers some distance towards the west. The direction of wind controls the dust from the quarrying area during the quarrying of stones as well as after the use of explosives like dynamite. The hill completely blocks the strong eastern winds which would have taken the quarrying dust to long distances towards the west which is the main quarrying site. Thus, the hill is so situated that the heavy particles cannot be transported to long distances by air and the fine dust particles settle down quite close to the site of quarrying, *i.e.*, 20–30 metres. Very strong winds from time to time diffuse these dust particles in the nearly sandy soil which is a natural way of diluting the metal concentration in the soil.

Rain water also accounts for removal of cadmium containing dust both from the hill (loosely attached after quarrying) and that which collects in the nearly open fields. Heavy downpour during rainy season washes the metal-containing dust to nearby drains and also to a seasonal river close to the site of quarrying. Thus, heavy particles remains in the open area of the quarrying site while the dust concentration continuously decreases. The rate of decrease, however, depends upon climatic conditions.

An investigation of the quarrying sites also revealed that extensive quarrying had been carried out in zones 2nd to 4th during the last 30 years. The height of the hills is also maximum in this area. It is therefore not surprising that the concentration of metal is high in these zones. The concentration of cadmium is also same in different samples of soil in these zones as found in the rock samples at different heights. Zone 1 has also high concentration of cadmium as found in zone 2nd to 4th. The quarrying started from this area and presently this is not the site of active quarrying. It appears that the concentration is still high on account of the following two reasons:

1. The particles containing cadmium are heavy and have remained in this zone in spite of strong winds and rains.
2. The dust from quarrying sites in zones 2nd, 3rd and 4th settles in this area due to closeness in normal days when strong winds and rains are absent.

It also appears from site inspection that dust covers maximum distance in the open space in zones 3rd and 4th and therefore, the minimum cadmium concentration even at 20 metres and beyond is 0.40 mg/L. The direction of wind is not favourable towards populated area in zones 5th and 6th and the cadmium concentration is low, *i.e.*, 0.15 mg/L.

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