Measurement of the Level of Some Heavy Metals in Fall-out Dusts at Rehoboth Town, Hardap Region, Namibia

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Authors' contributions

This work was carried out in collaboration between all authors. Author SAO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author NH collected, prepared the samples and supervised the laboratory procedures. Author JA performed literature searches and managed the analyses of the study. All authors read and approved the final manuscript.

Article Information

Original Research Article

ABSTRACT

Aims: To determine the levels of heavy metals in fall-out dust from Rehoboth town, Hardap region, Namibia.
Study Design: Modified open bucket samplers were used to collect the settleable particulate. Six "ordinary" open buckets were placed at different locations (Blocks A to F). In Rehoboth town. Each bucket's contents were filtered using a Buchner funnel connected to the diaphragm vacuum pump. The residues collected after the filtering were dried and transferred into clean, pre-labelled polyethylene bags and then transported to Analytical Laboratory Services, Windhoek Namibia, for further processing and analyses.

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Place and Duration of Study: Rehoboth town, Hardap region, Namibia, between September 2015 and December 2015.

Methodology: The samples were digested according to EPA method 3050B for Inductively Coupled Plasma-Optical Emission Spectrophotometer (ICP-OES) analysis. Ten (10) mL of each digestate was taken and mixed with equal volume of matrix modifier and then analysed using ICP-OES (ICP: Perkin Elmer Optima 7000 DV) for the levels of chromium, cadmium, lead, arsenic, manganese, zinc and nickel.

Results: The levels of heavy metals obtained showed the metals' enrichment of the dust fall ranging between 0.05 – 1.38 Block A; 0.06-37.44 Block B; 0.05-3.43 Block C; 0.05-4.68 Block D; 0.09-1.73 Block E and 0.09-1.56 Block F respectively. This showed very high enrichment for Block B and deficient to minimal, moderate enrichment for Blocks A, C, D, E and F. The results of contamination factors indicated moderate, considerate and highly contaminated dust fall with the heavy metals; which are related to common and input from anthropogenically induced sources.

Conclusion: Human activities in the town of Rehoboth, Namibia have obviously increased the levels of heavy metals in dust fall-out. The calculation of pollution load index (PLI) clearly points to deterioration of site quality. This obviously is a grave concern following environmental accumulation and non-biodegradation of heavy metal and hence, the need to have all major roads and inter linking street roads to be paved to mitigate the release of dust into the atmosphere.

1. INTRODUCTION

Fall out dust monitoring is becoming a preferred method to determine environmental pollution occasioned by dust from emission source to receptor [1]. This fall-out dust can be divided into fine and coarse particles. The former is referred to as Total Suspended Particulate (TSP), whilst thorack particles or PM10 (particulate matter with an aerodynamic diameter of less than 10 μm) fall in the finer fraction [2]. PM10 is associated with respirable health hazards for it represents particulate of size that would be deposited in, and damaging to, the lower airways and gas-exchanging portion of lung. TSP is usually of interest in terms of dust deposition (nuisance) [2].

Studies on the severity of fall out dust in urban areas all around the world have been well documented [3-8]. Due to the settling abilities of TSP near emission sources, studies have made classification of its reception pattern as ambient-outdoor, street-outdoor and indoor dust fallout [9-12]. Atmospheric deposition of heavy metals in dust has been described earlier [13-16]. The presence of heavy metals has been considered as indicators for contamination in surface soil, sediment and dust environment [17].

In recent years, studies have shown concerns about the potential contribution of ingested dust toward trace metal toxicities to human population. Research has shown that young children are particularly more likely to ingest significant quantities of dust than adult populations. This is informed by behavioural mouthing of non-food objects and repetitive hand/finger sucking [13,18].

Heavy metals are naturally occurring substances which are present in our environment at low levels. They exist as individual metals and also as metal compound which at a certain level present health risk to human population. Generally, exposure to these metals can be by ingestion (drinking or eating), inhalation and dermal contact. Thus, due to the growing concern for the potential contribution of ingested and inhaled dust towards heavy metal toxicities in human population-with little children more at risk, the need to study the levels of heavy metals in our environment cannot be over looked. For example, chromium has been found in rocks, animals, plants and soil. It exists in the form of liquid, solid, or gas. The element is used in metal alloys industries such as stainless steel; in protective coatings on metal; magnetic tapes; and pigments for paints, cement, paper, rubber, and other materials [19]. Chromium is required by the body in small amounts but this element can be toxic at higher quantities [20]. The U.S. Environment Protection Agency (EPA) and the International Agency for Research on Cancer (IARC) have classified inhaled Cr (VI) as a known carcinogen [21,22]. The World Health Organization (WHO) has determined that Cr (VI) is a human carcinogen. In similar report, the Department of Human and Human Services (DHHS) also determined that Cr (VI) compounds are known to cause cancer in human [23].

Cadmium has been known to be a very toxic metal. It is present in soils and rocks and has been widely used in industries for the making of batteries, pigments, metal coatings, and plastics. Cadmium finds extensive usage in electroplating [24]. Chronic exposure to Cd results in kidney damage, bone deformities, and cardiovascular health related problems [3].

Anthropogenic activities such as fossil fuel combustion, mining, and manufacturing have led to Pb distribution in diverse facets of environmental phenomenon. This includes air, soil, and water. Lead is employed in many different ways. It is used in the production of batteries, ammunition, metal product like solder and pipe, as well as X-ray shielding devices. Lead is highly toxic and can affect every human organ and system in the body [19]. Long-term exposure of adults to Pb can decrease performance in test that measures functions of the human nervous system [24].

In nature, arsenic exists in soil as oxysalts and sulphur containing minerals. The environmental chemistry of arsenic is similar to that of phosphorus. Its complex chemical form leads to multiple chemical species that differ in toxicity [25]. Neurotoxicity, liver injury, cardiovascular disease, and skin cancer are results of chronic exposure to inorganic arsenic [25].

Total Mn concentrations in soils are variable (1 – 3000 mg/kg). Soluble Mn^{2+} ions are readily available of all the different form of Mn in soil. The availability of Mn is influenced by pH. Reducing and other conditions could lead to excessive Mn^{2+} which could have toxic effect [26].

Zinc is an essential element in the human diet because it is required to maintain proper functions of the immune system. It is also important for normal brain activity and is fundamental in the growth and development of the foetus [27]. The Recommended Daily Allowance (RDA) for zinc is 15 mgZn/day for men and 12 mgZn/day for women. Ingestion of large doses (390 mgZn/day for 3 – 13 day, or about 27 gZn/day) of Zn can cause death [27]. If doses of 10 – 15 times higher than the RDA are taken over a long period, anaemia and damage to the pancreas and kidney can develop [28]. Vomiting, diarrhoea, abdominal cramping, and in some cases, intestinal haemorrhage can occur from long-term exposure to high (>85 mg/kg/day) doses of zinc [27,28].

Nickel is soluble in soil water and as true for metals, increases at low pH [29]. Inhalation of Ni produces respiratory tract cancer and allergic contact dermatitis aside from these problems, Ni toxicity appears quite low [19]. The purpose of this present study is essentially, therefore, to: (1) determine the levels of eight common heavy metals: chromium (Cr), cadmium (Cd), lead (Pb), arsenic (As), manganese (Mn), zinc (Zn), Nickel (Ni) and iron (Fe) in fall-out dust from Rehoboth town. (2) to calculate the enrichment factor, contamination factor and pollution load index for future reference and study in the area.

2. MATERIALS AND METHODS

2.1 Study Area

The study was undertaken in Rehoboth metropolis, a town in the Hardap Region of Namibia. The town is located on latitude 23°19'00''S and longitude 17°04'59''E with elevation above sea level of 1393 m (4570 ft) based on the global positioning system (GPS) geographical information recorded at the site on 09 September 2015. According to Namibia 2011 population and housing census preliminary result, Rehoboth metropolis has a population of 28,843 and density 44.4/Km^2. The town administratively; is subdivided into eight neighbourhoods, called blocks (Table 1). The oldest of the town is block A, B, and C. Shops, business activities as well as public services are located at block B. Block D is the location for high income inhabitants of the town while block E is home to low income dwellers. Blocks F, G and H are however the newest neighbourhoods. The town has only one paved road that runs through the town interlinking with the B1 national road from Windhoek, Namibia's capital city to the Southern part of the country. Vehicular activities and traffic congestion is also on the increased and has engendered the release of particulate matter into the environment. This has therefore pointed to the need to investigate environmental pollution indicators such as heavy metals with a view to checking unintended exposure of human population.

2.2 Sample Collection and Pretreatment

Modified open bucket samplers were used to collect the settleable particulate. This was based on the American Standard Test Method (ASTM) D1739 of 1998 [30]. Six "ordinary" open buckets were placed in each block so that fine

Table 1. Geographical coordinates and study site description

Name of site	Geographical coordinates	Site description
Block A	23°18'40.41"S 17°05'28.64"E	Residential, high population density, Heavy Traffic.
Block B	23°19'24.61"S 17°05'03.57"E	Low traffic, residential, Municipal offices.
Block C	23°19'50.45"S 17°04'32.44"E	Commercial, educational institution, residential, medium traffic.
Block D	23°19'52.49"S 17°04'18.32"E	Residential, heavy traffic, recreational centres.
Block E	23°19'29.23"S 17°05'52.42"E	Commercial (Welding, vehicle mechanic workshop), residential, heavy traffic, waste disposal.
Block F	23°18'25.68"S 17°05'11.78"E	Residential, heavy traffic, commercial

precipitating dust samples could be collected from all directions irrespective of wind direction. Settling particulate matter were collected in 5 L plastic buckets half filled with distilled water spiked with about 5 mL of biocide solution which served as an algaecides. The buckets were hoisted on steel holders at heights of about 2.6 m from ground level and left for 30 days of sampling period after which samples were transported to the laboratory. Once returned to the laboratory of the Namibia University of Science and Technology, each bucket's contents were filtered using a Buchner funnel connected to the diaphragm vacuum pump. The residues collected after the filtering were dried and transferred into clean, pre-labelled polyethylene bags and then transported to Analytical Laboratory Services, Windhoek Namibia, for further processing and analyses.

2.3 Sample Digestion

The samples were digested according to EPA method 3050B for Inductively Coupled Plasma-Optical Emission Spectrophotometer (ICP-OES) analysis. A known amount (1.00 g) of each sieved particulate was transferred into a digestion vessel and 10 mL of 1:1 nitric acid (HNO_3) was added, mixed thoroughly and covered with a watch glass. Thereafter, the samples were heated to 90°C and refluxed at this temperature for 10 minutes under room temperature. Then, 5 mL of concentrated HNO_3 was added to each, covered and refluxed again at 90°C for 30 minutes. The solutions were then allowed to evaporate without boiling to approximately 5 mL each and cooled again for 5 minutes. This process was then followed by the addition of 2 mL of deionised water plus 3 mL of

30% hydrogen peroxide (H_2O_2) to each. The vessels were covered and heated just enough to warm the solutions for the peroxide reaction to start [3,31]. This process was continued until effervescence subsided and the solutions were cooled.

The acid-peroxide digestates were covered with watch glasses and heated until the volume reduced to approximately 5 mL again. After which 10 mL of concentrated hydrochloric acid (HCl) was added to each, covered and heated on a heating mantle, then refluxed at 90°C for 15 minutes. After cooling, each digestate was filtered through Whatman No. 41 filter paper into a 100 mL volumetric flask and the volume made up to the mark with deionised water [31].

Ten (10) mL of each digestate was taken and mixed with equal volume of matrix modifier [31] and then analysed using ICP-OES (ICP: Perkin Elmer Optima 7000 DV) for the levels of chromium, cadmium, lead, arsenic, manganese, zinc and nickel.

2.4 Data Analysis

Data generated from triplicate analyses were subjected to treatment of mean and standard deviation, inter-elemental correlations as well as analysis of variance at $P > 0.05$ error protection to determine the significance of data variation between sampled sites.

2.5 Assessment of Site Contamination

In the present study, the site contamination was assessed using Enrichment Factor (EF) [32,33], Contamination Factor (CF) [34] and Pollution

Table 2. Contamination criteria based on Enrichment factor (EF) and Contamination factor (CF) [32], [33-34]

Enrichment factor		Contamination factor	
Classification	**Degree of enrichment**	**Classification**	**Degree of contamination**
$EF < 2$	Deficient to minimal	$CF < 1$	Low
$2 < EF < 5$	Moderate	$1 \leq CF < 3$	Moderate
$5 < EF < 20$	Significant	$3 \leq CF < 6$	Considerate
$20 < EF < 40$	Very high	$CF > 6$	High
$EF > 40$	Extremely high		

load Index (PLI) [35]. The EF method normalizes the measured heavy metal content in the samples with respect to a reference sampled element [36]. In this study, Fe is the reference element of normalization. Each of these assessment criteria was calculated using the following equations:

$$EF = [C_{metal} / C_{normalizer}] \; sample \; / \; [C_{metal} / C_{normalizer}] \; control \qquad (1)$$

$$CF = C_{metal} / C_{control} \qquad (2)$$

$$PLI = [CF_1 \times CF_2 \times CF_3 \times \ldots \ldots \ldots \times CF_n]^{1/n} \qquad (3)$$

where C_{metal}, is the concentrations of heavy metal in sample, $C_{normalizer}$ is the concentration of the normalizer and n represent number of elements respectively. Table 2 summarises the contamination criteria based on enrichment factor (EF) and contamination factor (CF). Table 3 summarises the contamination criteria based on pollution load index (PLI).

Table 3. Contamination criteria based on Pollution load index (PLI) [35]

Classification	Degree of enrichment
PLI < 1	No pollution
PLI = 1	Baseline levels of pollutant present
PLI > 1	Deterioration of site quality

3. RESULTS AND DISCUSSION

3.1 Assessment of Metal Concentration

Table 4 presents the concentration of heavy metals in mg/kg investigated in fall-out dust in Rehoboth town, Namibia. These metals include chromium (Cr), cadmium (Cd), lead (Pb), arsenic (As), manganese (Mn), iron (Fe), zinc (Zn) and nickel (Ni). The study showed the average concentrations (mg/kg) of the metals decreasing in the order Fe > Zn > Mn > Cr > Ni > As > Pb > Cd for Blocks A and B, Fe > Zn > Mn > Cr > Ni > Pb > As > Cd for Blocks C and E, Fe > Zn > Mn > Cd > Cr > Pb > Ni > As for Block B and Fe > Zn > Mn > Ni > Cr > Pb > As > Cd for Block F. The present study has shown that Fe recoded the highest concentration across all the Blocks. These elevated levels of Fe may be because its natural sources (1.5%) vastly dominate its input [32]. Also, the possibilities of anthropogenic activities such as incidental wear off of car bodies; incineration of iron-rich wastes materials, welding and blacksmith activities that are carried out in the town may be a contributing factor to the high iron concentrations. The results obtained for each element are discussed.

The concentrations of Cr in the fall-out dust ranged from 8.00 – 320 mg/kg with an average value of 130.70 mg/kg. The study revealed that the average concentration of Cr in the fall-out dust is 62 times higher than the chromium concentration in the control site (2.10 mg/kg). Studies have shown a correlation between urban growth and Cr concentration occasioned by industrialisation [36]. Other source of Cr in urban cities is believed to be due to corrosion of vehicular parts [37].

Cadmium concentrations were found in the range of 6.00 – 18.00 mg/kg with an average value of 11.50 mg/kg. The value for the control site revealed a level of 4.61 mg/kg. Naturally in the soil, the allowable limits of Cd concentrations should not exceed 3 mg/kg [36]. The findings of the concentrations of Cd in this study did not compare favourably with similar studies on dust fall-out in Katima Mulilo, Namibia where the Cd concentration ranged from 1.83 – 0.47 mg/kg [13].

The concentration of Pb ranged from 5.00 – 60.00 mg/kg with Block B recording the lowest

values and Block C having the highest concentration of Pb. The average concentration (34.00 mg/kg) in this study is 16 times higher than the concentration of Pb in the control site (2.10 mg/kg). The levels of Pb in the study sites were within permissible limits of 100 mg/kg [38]. However, anthropogenic sources of Pb in the environment are mainly from automobile exhaust and vehicular emission which includes; tire wear, bearing wear and break lining wear [39].

The concentration of As in the fall-out dust ranged from 2.00 – 68.00 mg/kg with an average value of 28.00 mg/kg. The average value of As in this study was found to be 12 times higher than the control site (2.30 Mg/kg). Apart from the value obtained from Block B (2.00 mg/kg) all other sites are found to be higher than the critical value of 16 mg/kg (average crustal abundance) [40]. Arsenic is highly carcinogenic has no nutritional value for plant and animals [36].

The concentrations of Mn ranged from 37.00 – 909.00 mg/kg with an average value of 605.33 mg/kg. The study found the average value to be 16.4 times the control value (37.00 mg/kg) in the fall-out dust. An acceptable value of 1000 mg/kg for Mn in an uncontaminated soil was recommended in the study by [41].

Zinc concentration was obtained in the range of 84.00 – 2831.00 mg/kg. The average value for Zn was calculated as 1807.83 mg/kg, this value is higher than the reported acceptable value of 300 mg/kg for Zn element in soil [36]. However, elevated presence of this amount of Zn in the fall-out dust may be attributed to the fact that Zn compounds are used as anti-oxidants and in products such as detergent/depressants to improved agents for motor oil. Equally, vehicular brake linings and tire wear have been identified as other possible sources of Zn [38].

Nickel concentrations were found in the range of 3.00 – 114.00 mg/kg with an average value of 70.00 mg/kg. The value for the control site revealed a level of 2.10 mg/kg; this value is 33 times lower than the average value obtained from the fall-out dust. Some possible sources of Ni in the fall-out dust could be due the corrosion of vehicular parts [38].

3.2 Enrichment Factor

The calculation and evaluation of enrichment factor (EF) has been extensively used to determine whether a certain element has additional or anthropogenic sources other than it's predominate sources [36]. The values obtained for the enrichment factor for all the metals monitored in the fall-out dust are presented in Table 5. These results suggest that most of the metals across all the sampled sites have deficient to minimal enrichment. However, the EF value obtained for Cd (37.44) in Block B is indicative of very high enrichment. Equally, The EF values of some metals in Blocks B (Pb-2.06), C (Cr-3.43) and D (Cr-4.68, Ni-2.08) points to moderate enrichment in the fall-out dust.

If the EF value approaches unity, then it is suggestive of predominant crustal sources. In general, if EF value is greater than five (5), it implies that a large fraction of the element can be attributed to non-crustal or anthropogenic sources [36]. The high EF value for Cd in Block B could be as a result of mainly anthropogenic sources such as industrial emissions. Fe has been used in this current study as reference element following the assumption that its content in the earth crust has not been disturbed by anthropogenic activities, and it has been chosen as the element of normalization because natural sources (98%) vastly dominate its input [42].

3.3 Contamination Factor

The degree of contamination of the fall-out dust was assessed based on contamination criteria proposed by [34] (Table 2). The contamination factors of all the assessed metals are presented in Table 6. This study shows that Block A suffers moderate to high contamination. The classifications in Block A are as follows; Zn (1.29 - moderate contamination), As, Pb, Mn, Ni, Cr and Cd (8.26, 8.57, 19.14, 21.90, 30.48 and 33.33 – high contamination). The contamination factors for Block B ranged from low to high with Ni, Zn, and As (0.04, 0.07 and 0.87) recording low contaminations, Mn (1.00), Pb (2.38) with moderate degree of contamination, Cr (3.81) with a considerable contamination and Cd (43.33) recording a high degree of contamination. Similar results recorded in Block C suggest moderate contamination of Zn (2.13) and high contamination with the rest of the metals monitored. In Block D, the calculated values of the contamination factors showed moderately to high contamination of the fall-out dust with the various metals. The degree of contamination showed moderate contamination of Zn (1.41) and high contamination of all the other metals. Block E and F show a similar pattern as Block C and D with Zn registering moderate contaminations (1.77 and 2.36) and the other metals recording high degree of contaminations.

Table 4. Concentrations in mg/kg of some heavy metals in fall out dust in Rehoboth, Namibia

Locations	Cr	Cd	Pb	As	Mn	Fe	Zn	Ni
Block A	64.00±0.20	10.00±0.18	18.00±0.10	19.00±0.13	708.00±0.18	56209.00±0.13	1554.00±0.10	46.00±0.15
Block B	8.00±0.20	13.00±0.12	5.00±0.21	2.00±0.20	37.00±0.17	2693.00±0.50	84.00±0.15	3.00±0.17
Block C	320.00±0.10	6.00±0.50	60.00±0.13	18.00±0.10	620.00±0.50	103300.00±0.20	2560.00±0.18	110.00±0.10
Block D	257.00±0.12	18.00±0.17	42.00±0.18	68.00±0.06	621.00±0.13	60807.00±0.13	1693.00±0.21	114.00±0.18
Block E	69.00±0.52	10.00±0.56	46.00±0.23	30.00±0.05	737.00±0.10	44750.00±0.18	2125.00±0.17	63.00±0.18
Block F	66.00±0.13	12.00±0.06	36.00±0.52	34.00±0.18	909.00±0.18	59738.00±0.14	2831.00±0.06	84.00±0.14
Average	130.70±0.21	11.50±0.27	34.00±0.22	28.00±0.12	605.33±0.21	54582.83±0.21	1807.83±0.15	70.00±0.12
Control	2.10±0.23	0.30±0.12	2.10±0.10	2.30±0.05	37.00±0.16	2327.00±0.31	1250.00±0.50	2.10±0.18

Data presented are mean±standard deviation of triplicate analyses

3.4 Pollution Load Index (PLI)

To properly evaluate the levels to which the six sites suffer contamination, the pollution load index (PLI), given by equation 3 was used. The PLI give a measure of the degree of overall contamination at any given location. The PLI values in the study decreased in the order of Block C > Block D > Block F > Block E > Block A > Block B (Table 5). However, all the sites show deterioration of site quality except Block B with baseline levels of the presence of pollutant. This finding is suggestive of input from anthropogenic sources presumably from human activities which includes; improper handling of municipal waste, vehicular activities and some commercial activities that releases metals into the air.

3.5 Inter-elemental Correlation (r) Analysis of the Heavy Metals

The results of inter-elemental correlation coefficients recorded in the fall-out dust is indicative of extremely weak ($r < 0.1$), weak ($r = 0.1 - 0.5$), strong ($r > 0.5 - 0.9$), extremely strong ($r > 0.9$) and perfect ($r = 1.0$) correlations between the monitored metals (Table 6). The strong correlations between Pb and Cr, Fe and Cd, As and Cd, Fe and Pb, Zn and Pb, Ni and Cr, Ni and Fe, Ni and Zn, Zn and Fe, Fe and Mn,

Zn and Mn suggest common anthropogenic origin presumably from industrial emission and vehicular activities. Thus, these metals could accumulate simultaneously in the atmosphere and during dust precipitation and deposition. The negative correlations between some of the metals suggest that those elements have different sources of anthropogenic inputs and hence, their independent degree of accumulation in the fall-out dust.

3.6 Interpretation of Metal Source Using the Principal Component Analysis (PCA)

A factor analysis was carried out to further classify the major controlling factors that determine the distribution of heavy metals in the fall-out dusts. Table 8 represents the PCA results consisting of three (3) factors. Factor 1 is characterized by moderate loading which explained 62.57% of the total variance. Factor 2 explained 22.13% of the total variance and with a moderate loading to very high loading on As and Cd indicated a mixture of industrial waste, vehicular emission/oil combustion. Factor 3 explained 12.38% of the total variance and correlate with high to very high loading on Mn. Manoli et al. [43] reported that road side dust deposition had high loading on Mn. Thus, factor 3 is assigned road/soil dust.

Table 5. Enrichment factors of the heavy metals at the study locations

Heavy metal	Block A	Block B	Block C	Block D	Block E	Block F
Cr	1.26	0.16	3.43	4.68	1.71	1.22
Cd	1.38	37.44	0.45	2.30	1.73	1.56
Pb	0.35	2.06	0.64	0.77	1.14	0.67
As	0.34	0.75	0.18	1.13	0.68	0.58
Mn	0.79	0.89	0.38	0.64	1.04	0.96
Zn	0.05	0.06	0.05	0.05	0.09	0.09
Ni	0.91	1.23	1.78	2.08	1.56	1.56

Table 6. Contamination factors and pollution index of heavy metals from study locations

Heavy metal	Block A	Block B	Block C	Block D	Block E	Block F
Cr	30.48	3.81	152.38	122.38	32.86	31.42
Cd	33.33	43.33	20.00	60.00	33.33	40.00
Pb	8.57	2.38	28.57	20.00	21.91	17.14
As	8.26	0.87	7.83	29.57	13.04	14.78
Mn	19.14	1.00	16.76	16.78	19.92	24.57
Zn	1.29	0.07	2.13	1.41	1.77	2.36
Ni	21.90	0.04	52.38	54.29	30.00	40.00
PLI	12.15	0.99	74.51	24.68	16.48	18.49

Table 7. Inter-elemental correlation analysis in Rehoboth dust fall-out

Heavy metal	Cr	Cd	Pb	As	Mn	Fe	Zn	Ni
Cr	1.0000							
Cd	-0.0972	1.0000						
Pb	0.7726	-0.3211	1.0000					
As	0.4577	0.6500	0.4461	1.0000				
Mn	0.2126	-0.1736	0.5911	0.4935	1.0000			
Fe	0.8122	-0.4504	0.8344	0.3066	0.6382	1.0000		
Zn	0.4403	-0.3624	0.8081	0.3831	0.9050	0.8054	1.0000	
Ni	0.8487	0.0227	0.8745	0.7211	0.6421	0.8528	0.7733	1.0000

Table 8. PCA loading calculated for eight chemical variables in Rehoboth dust fall-out

Variable	Factor 1	Factor 2	Factor 3
Cr	0.3487	0.0694	**-0.6160**
Cd	-0.0944	**0.7311**	0.0377
Pb	*0.4143*	-0.0839	-0.1410
As	0.2597	*0.6009*	0.1127
Mn	0.3405	-0.0246	**0.6362**
Fe	*0.4134*	-0.1962	-0.1572
Zn	0.3983	-0.1540	0.3759
Ni	*0.4300*	0.1728	-1.1254
Eigen value	5.0053	1.7703	0.9908
Percentage of Variance	62.57%	22.13%	12.38%
Cumulative percentage	62.57	84.70	97.09

Note: Bold: *high to very high loading (>0.6)*
Bold & Italic: *Moderate loading (between 0.4 and 0.6)*
Regular: low loading (<0.4)

4. CONCLUSION

The results of the heavy metals determined in the fall-out dusts in Rehoboth town revealed the presence of chromium, cadmium, lead, arsenic, manganese, iron, zinc and nickel. The calculated values of the enrichment factors suggested deficient to minimal and very high enrichment for some of the metals. The contamination status of fall-out dust with the heavy metal indicated moderate, and considerable to very high degree of contamination. The values obtained for the pollution load index points to site deterioration with the heavy metals except for Block B with baseline levels of the presence of pollutant. Thus, it is recommended that all major street and inter linking roads in the town be paved to reduce the emission of surface dust into the atmosphere.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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