Heavy Metals in Atmospheric Dust Deposition in Qalyubia governorate Egypt: Occurrence and Diverse Impacts

1. Abstract:

The southern delta region of Egypt has serious environmental and public health issues due to heavy metal pollution. (2) The air in Qalyubia has higher concentrations of metals including cadmium (Cd), cupper (Cu), zinc (Zn), and nickel (Ni) due to the region's intense agricultural practices and industrial discharges. The ring road and the Banha Cairo regional route also traverse the governorate with heavy traffic. The sources, distribution, and ecological effects of heavy metals in the south Nile delta region are examined in this study. (31)Dust fall sampling allows us to pinpoint important pollution hotspots. The findings show a relationship between increased levels of contaminants and being located nearby industrial sites (14), showing that human activity is a significant source of pollution. We also evaluate the possible hazards to human health, especially for communities. (10)

Keywords: Heavy Metals, Contaminants, Hazards, Communities

2. Introduction:

Egypt, characterized by its arid climate and extensive desert landscapes, experiences significant atmospheric dust deposition enriched with heavy metals. Egypt's unique environmental setting, dominated by desert expanses and limited precipitation, facilitates the transport and deposition of atmospheric dust enriched with heavy metals. These metals, essential for industrial and agricultural applications, pose environmental challenges due to their persistence and potential toxicity. (2)

The major sources of air pollution in southern Delta Egypt typically include: Industrial Emissions: From factories and industrial facilities, including those producing chemicals, cement, and other heavy industries. (5) Vehicle Emissions: Particularly from cars, trucks, and buses, contributing to exhaust fumes and particulate matter. Agricultural Activities: Such as burning of crop residues and emissions from livestock. Urban Activities: Including residential heating and emissions from households. (7) Natural Sources: Dust storms and natural emissions. Efforts to mitigate these sources include stricter regulations, cleaner technologies, and public awareness campaigns. (6)

2.1. Occurrence and Sources of Heavy Metals:

Sources of heavy metals in Egyptian dust include natural mineral deposits, urban and industrial emissions, and agricultural practices. (2) Unique trace elements may be released by certain processes, such as copper from copper smelters, zinc from incineration, lead from lead smelters, nickel and vanadium from heavy oil combustion, and metal manufacturing and processing [4] In Egypt, these metals are sourced from geological formations rich in minerals, industrial emissions, vehicular exhaust, and agricultural inputs like pesticides and fertilizers. Atmospheric dust acts as a carrier, transporting these metals over considerable distances and depositing them in terrestrial and aquatic ecosystems. The spatial distribution of heavy metals in Egyptian dust varies, influenced by proximity to industrial zones, transportation routes, and agricultural intensification. (1)

Heavy metals encompass elements with high atomic weights and toxicity potential, such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As). (13) In Egypt, these metals are sourced from geological formations rich in minerals, industrial emissions, vehicular exhaust, and agricultural inputs like pesticides and fertilizers. Atmospheric dust acts as a carrier, transporting these metals over considerable distances and depositing them in terrestrial and aquatic ecosystems. (11) The spatial distribution of heavy metals in Egyptian dust varies, influenced by proximity to industrial zones, transportation routes, and agricultural intensification. (12)

2.2. Environmental and Health Impacts:

"There are several negative effects on the ecosystem and human health when heavy metals accumulate in airborne dust deposition. In terms of ecology, metals can build up in soils, limiting plants from absorbing nutrients and affecting terrestrial ecosystems. Metals via airborne dust can sediment in aquatic ecosystems, contaminating waterways, reducing aquatic biodiversity, and endangering human health by bioaccumulating in aquatic food chains. Receiving and inhaling contaminated particulate matter is the main way that humans are exposed to airborne heavy metals, which can cause neurological issues, respiratory disorders, and developmental delays, especially in those at risk like pregnant women and children". (1), (2)

Heavy metals pose significant risks due to their tendency to bioaccumulate. Bioaccumulation refers to the gradual buildup of a chemical within a living organism over time, especially when compared to the environmental concentration of that chemical. These metals are absorbed at a faster rate than they can be metabolized or excreted. Cadmium (Cd) is among the most prevalent heavy metal pollutants, and its toxic effects stem from its chemical similarity to zinc (Zn), which is an essential micronutrient for plants, animals, and humans. Once cadmium is taken up by an organism, it remains in the body for many years, exhibiting biopersistence. Acute exposure to high levels of cadmium through inhalation can lead to lung-related issues in humans, including bronchial irritation and compromised lung function. Copper (Cu), while crucial for human existence, can lead to anemia, liver and kidney damage, as well as gastrointestinal issues when present in excessive amounts. Individuals with Wilson's disease are particularly vulnerable to the adverse effects of copper overexposure. Manganese serves as one of three toxic essential trace elements; it is vital for human survival, yet it can be harmful at elevated concentrations.

2.3. Ecological indices in Egypt:

The natural background concentrations of nickel (Ni), copper (Cu), and cadmium (Cd) in Egyptian soils can vary based on regional geology and environmental factors. However, general background levels for these metals in soils are typically as follows:

Nickel (Ni): Background concentrations of nickel in soils can range from 10 to 100 mg/kg, with typical values around 20 mg/kg in uncontaminated soils.

Copper (Cu): Copper concentrations usually range from 5 to 50 mg/kg in natural soils, with average values around 20 mg/kg for uncontaminated soils

Cadmium (Cd): Cadmium is often found at much lower concentrations, typically between 0.1 and 1 mg/kg in uncontaminated soils, with average natural levels around 0.5 mg/kg [9], [8].

These values represent average natural background concentrations and can be used as reference points when assessing soil contamination. For precise values specific to Egypt, local environmental and soil studies should be consulted.

Contamination indices and ecological risk indices were analyzed to evaluate heavy metal pollution using both single and integrated criteria, contamination indices and ecological risk indices were examined. "The pollutant load index (PLI), the degree of contamination (DC), and the potential ecological risk index (RI) were computed as integrated indices in this study, while the contamination factor (Cf), ecological risk factor (Er), and index of geo-accumulation (Igeo) were computed as single indices". (3)

2.4. Aim of Paper:

"Assessment of the contamination in the Nile Delta is quite rare that important to throw light on it to improve researches and help decision makers to Establish strict regulations and enforcement strategies to manage emissions" (15). "The study aims to elucidate the occurrence, sources, and impacts of heavy metals (Cu, Zn, Cd, Ni) in atmospheric dust deposition across Qalyubia Governorate Southern DELTA Egypt, emphasizing their ecological and human health ramifications". (2)

2.5. Mitigation Strategies and Future Directions:

"Effective mitigation strategies are crucial for minimizing the environmental and health impacts of heavy metals in Egyptian dust deposition. These strategies include regulatory measures to control industrial emissions, sustainable agricultural practices to reduce metal contamination in soils, and public health interventions to mitigate exposure risks. Continued research efforts should focus on monitoring heavy metal levels in dust deposition, assessing their long-term effects on ecosystems and human health, and developing targeted interventions to safeguard environmental quality and public health in Egypt". (10)

3. Materials and Methods:

3.1. Description of the Study Area:

QUALYBIA Governorate is located in the south of Nile delta and extends from latitude 31° 25′ N to 31° 5′ N and longitude 30° 34′ E to 30° 5′ E and occupies an area of 1.001 km2 stretching along the banks of the river Nile [Fig. 1]. It includes five residential districts and two industrial zones (17). Location situated in the east Nile region at the head of the Delta. It is bordered to the south by Cairo and Giza Governorates, to the north by Dakahleya, and Gharbyah, to the east by Sharqiyah, and to the west by Menofya.

Fig (1): selected monitoring sites(source: Google Earth)

In addition, Shoubra El khima El Khaima hosts the largest industrial cluster including several factories of: spinning and weaving, electric appliances, plastics, vehicles, oil refining, food packing and processing, metal products (13)
The over all of this study conducted in [2024] QUALYBIA Governorate NILE DELTA area evaluated the environmental and health hazards of ambient particulate matters included some of their heavy metals content, in order to trends in concentration of this substances.
QUALYBIA Governorate's population in 2000 had a population of 5.995.717 residents. And was chosen for this study because it is a rapidly developing area, contains many large industrial activities, two industrial zones, both located south of the city. There are various types of industry the majority of industrial activities.
QUALYBIA Governorate has an arid [a hot dry climate. In summer, the prevailing semiarid conditions in the area investigated, rainfall occurs only in the winter season, from November to April; humidity 58%, the temperature is between 22°C: 37°C in summer and the temperature winter is between 9°C :19°C. (16)

In selected sites monitoring heavy metal contents through were asses the state of air pollution in it and performed the health risks and the different sources of pollution which related to industrial, agriculture, domestics, urban activities. (16)

Table (1)**:** selected sites of the collected samples of ambient air dust fall.

Site	Description
Site (1)	Banha is located in heavy traffic location.
Site (2)	Shoubra El khima is located in industrial heavy traffic location.
Site (3)	Obour 1 is located in medical industrial area.
Site (4)	Obour 2 is located in residential location.
Site (5)	Kafr.Shukr is located in rural location.

Table (2) selected sites of the collected samples

ID	Site	Area Type	Latitude (N)	Longitude (E)
1	Banha	Residential	31°19`25"	30°47`32"
2	Shoubra	Industrial-traffic	31°23`73"	30°12`20"
3	Obour (industrial)	Urban	31°26`28"	30°47`51"
4	Obour (rural)	Urban	31°45`50"	30°21`59"
5	K. Shukr	Rural	31°25`63"	30°25`64"

3.2. Method:

Samples were collected from different five sites Table (1) The collected samples represent dust fall from ambient air deposited in glass jar (17 cm height and 8 to9 cm diameter) during 30 days in period from (Dec. 2018 to Nov. 2019). The sampling sites were selected from areas having different pollution levels originating from the traffic den- sites, human population, heavy traffic, economic units that produce pollutants from different industrial activities. All statistical analyses were performed by using the Microsoft Excel 2007. Using Stat soft statistical package, STATISTICA for Windows, Copyright Stat Soft, and Inc.

3.3. SAMPLING OF TOTAL DEPOSITED MATTERS:

Site Selection

Six locations were selected for dust fallout monitoring. Monitoring was done for one month at each location in each season. Details of the selected locations are as follows: Table (2) Dust Fall cylindrical container should be located on a stand at least 1.2m from the support surface to measure the dust fall. Same was used for the dust fall monitoring using approach and methodology adopted is described in subsequent section.

Dust Fall Collector:

Dust fall stations were mounted 1.3 m high tripods to avoid the collection of dust picked up by wind eddies. The container was replaced monthly. The collectors were exposed to the atmosphere for a sampling period of 30 days. The content of dust fall was dried at 105°C to a constant mass, and then it was weighed and the quantity of dust fall was computed in $\mu g/m^2$. month as depicted in detail below .

Fig. (2): Dust Fall Collector Model

3.3.1 Total Heavy Metal Digestion

In order to digest dust samples for atomic absorption spectroscopy analysis, 0.5 g of sample was placed in a covered Teflon beaker (to avoid the loss of Cd and Pb) containing a mixture of high purity HNO3(2.5mL)/percholoric acid HClO4 (2.5 mL) and allowed to remain overnight at ambient temperature. After slow evaporation to dryness, 1 mL of HNO3 was added and the solution was again evaporated to ryness, after which, the residue was extracted with 0.1 N HCl and diluted bi-distilled water, filtered on Whatman prewashed filter paper and diluted with 1% HNO3 in a 25 mL polyethylene bottle.

3.3.2 Soluble Heavy Metal (Available) Extraction

The soluble heavy metal (available) was extracted in plastic tubes from 1 g of dust material and 10 mL of 0.1 M sodium acetate (0.1 M NaOAc) for 24 h in the dark by agitating with a magnetic stirrer. The extract was centrifuged, filtered (0.22 um pore size) and acidified with 65 vol. – % HNO3 (BDH, HNO3 super pure). Blank solutions were prepared in the same manner as that employed for the real dust samples, for both total and available heavy metal procedures.

3.3.3. Ecological Risk Assessment of Heavy Metals

Different factors were used to identify the soil contamination and pollution. Some of the factors used in the current study are described in the following sections.

Geo-Accumulation Index (I_{geo})

The geo-accumulation index (I_{geo}) is generally used to quantify the anthropogenic contamination in surface soil as introduced by Muller (1981) [18] and corroborated by the prominent works of Forster et al., 1993 [19]; Loska et al., 2003 [20]; Lu et al., 2009; 2010 [21,22]; Gowd et al., 2010 [23]; and Manoj et al., 2012 [24]. This index evaluates the contamination levels by comparing present concentrations with background levels (Table 6) [25–27]. Igeo is expressed as Equation (1a):

$$(I_{geo}) = \log 2\ [C_n/1.5\ B_n] \qquad (1a)$$

where Cn and Bn are the measured and background concentrations, respectively, of the metal (n) and 1.5 is the correction factor used to account for possible variability in the background data due to lithological variation. Metal concentrations of average continental crust were used as the background concentrations for metals [28]. According to Muller (1981) [18] classified Igeo values into 6 classes.

(0): practically unpolluted (Igeo < 0).
(1): unpolluted to moderated polluted (0 < Igeo < 1).
(2): moderately polluted (1 < Igeo < 2)
(3): moderately to strongly polluted (2 < Igeo < 3).
(4): strongly polluted (3 < Igeo < 4).
(5): strongly to extremely polluted (4 < Igeo< 5).
(6): extremely polluted (Igeo > 5).

Contamination Factor (CF) and Contamination Degree (CD)

The CF and CD are used to assess the pollution load of surface soil dust with respect to heavy metals. The CF for each metal is calculated according to Equation (1b) [31,48,53]:

$$CF = C_{metal}/C_{background} \qquad (1b)$$

where CF is the contamination factor and Cmetal is the concentration of metal in surface soil dust. Cbackground is the background value for the metal. CD is calculated as the sum of all contamination factors for each sample in Equation (1c), and n is the number of metals [54].
The CF and CD were classified into four groups according to Nasr et al., 2006; Rastmanesh et al., 2010; Mmolawa et al., 2011; and Sherif and Atwany, 2019 [31,53,55,56], as shown in Table (5).

$$CD = \sum(CF1 + CF2 + CF3 + CF4 \ldots CFn) \qquad (1c)$$

Ecological risk factor (Er)

An ecological risk factor (Eri) to quantitatively express the potential ecological risk of a given contaminant also suggested by [29].

$$Er = Tr \times Cf \qquad (1d)$$

Where Tr is the toxic-response factor for a given substance, and Cf is the contamination factor. The Tr values of heavy metals suggested by [29]. The Tr values of Cu, Cd, Ni and Zn are 5, 5, 3, and 1, respectively. The following terminologies are used to describe the risk factor Er <40low potential ecological risk;40 <Er < 80Moderate potential ecological risk;80 <Er < 160 Considerable potential ecological risk; 160<Er < 320High potential ecological risk; Er > 320 Very High potential ecological risk.

Results and discussion

Dust fall deposition rate

Table (3): seasonal average of fall rate (g\m^2.month)

	Shoubra Elkhaima	Obour (1)	Obour (2)	banha	Kafr Shokr
winter	**1.24**	**0.32**	**0.30**	**0.66**	**1.03**
spring	**1.83**	**0.91**	**0.93**	**1.09**	**1.33**
summer	**0.91**	**0.78**	**0.77**	**0.88**	**1.24**
autumn	**1.41**	**0.81**	**0.90**	**0.90**	**1.64**

Tables (3) and show the Seasonal variation of dust fall rate (g\m^2.month) in studied area during the year that can be varied from one site to anther depending on the nature of the site of sampling, surrounding activities and the metrological condition.

seasonal average of dust fall rate was clear in The concentrations of the majority of dust-borne components varied with the seasons, rising in the spring and fall and decreasing in the summer and winter In the dust samples, the mean amounts of every element under investigation were higher than the corresponding background values in the soil samples.

The highest rates of dust deposited were recorded in autamn season due to several factors such as rain fall which consider the first washout the dust particulate from atmosphere. Also related with variable winds occur during these seasons it shows also relative high rates of deposition during springs as a result of local hot southeastern winds called khamasin wind, Minimum rate of deposited dust showed in summer with lowest wind speeds, high temperature.

The present study was under taken that Dust-borne Cd, Cu, Ni, and Zn all showed the same spatial distribution patterns. Their hot spot locations were mostly connected to industrial areas and dense traffic.(34) high rates of dust fall are found in the industrial area in Shoubra Elkhaima due to rapid growth of industrialization beside the traffic densities which emit a heavy deposition.

RURAL site in kafr Shukr and its surrounding areas affect badly by Burning rice straw in harvest season, bad air quality in autumn from mid-August to mid-November called black cloud season also because of unpaved roads in all streets. Sampling site in Banha Is located in heavy traffic location (Main Park of city) that cause close values of pollution during seasons.

__Heavy Metals Concentrations in Particulate Matter (PM10)__

Table (4): Annual average, stander deviation, of heavy metals in samples (PM_{10}) collected

Site	Statistic analysis	Cd	Cu	Ni	Zn
Shobra El Khima	mean	7.46	0.22	0.03	0.32
	s. dv+	2.12	0.16	0.01	0.10
Obour (1)	mean	6.67	0.16	0.03	3.01
	s. dv+	6.05	0.14	0.03	3.16
Obour (2)	mean	4.02	0.13	0.02	0.50
	s. dv+	1.63	0.08	0.01	0.48
Banha	mean	2.48	0.10	0.03	2.07
	s. dv+	1.12	0.05	0.02	0.85
Kafr Shukr	mean	4.18	0.13	0.05	3.69
	s. dv+	0.79	0.05	0.01	0.67

Higher annual mean concentration levels of most heavy metals in Shoubra Elkhaima the results showed that the heavy metal concentrations found were arranged in the following order: Ni (0.03 mg/m^3) > Cu (0.22mg/m^3) > Zn (0.32 mg/m^3) > Cd (7.46mg/m^3). These higher concentrations can be attributed to local emissions from industrial activities in

Qalyubia governorate region as Shoubra El-Khima is located close to the moasasaa power station, and various industrial activities, incomplete burning of fuel. Lowest annual mean concentrations of heavy metals in the ambient air (PM10) are in Banha. The results showed that the heavy metal concentrations found were arranged in the following order: Ni (0.03mg/m3) > Cu (0.10 mg/m3) > Zn (2.07 mg/m3) > Cd (2.48 mg/m3). These results may be attributed to unpaved roads and various human's activities.

Contamination Factor (CF) and Contamination Degree (CD)

Table (5): Contamination Factor (CF) and Contamination Degree (CD)

	contamination factor (Cf)					the degree of contamination
	location	**Cd**	**Cu**	**Ni**	**Zn**	**(Cd)**
1	Shoubra El khima	7.64	0.86	3.27	0.22	12
2	Shoubra El khima	11.25	0.12	0.56	0.07	12
3	Shoubra El khima	5.59	0.45	1.00	0.10	7
4	Shoubra El khima	8.68	0.33	0.75	0.06	10
5	Obour (1)	1.99	0.37	0.84	0.10	3
6	Obour (1)	5.61	0.38	1.23	0.05	7
7	Obour (1)	4.81	0.67	1.15	0.08	7
8	Obour (1)	6.11	0.14	0.32	0.01	7
9	Obour (2)	1.83	0.88	2.95	0.23	6
10	Obour (2)	5.74	0.31	0.84	0.16	7
11	Obour (2)	4.74	0.69	1.46	0.21	7
12	Obour (2)	5.56	0.32	1.13	0.04	7
13	banha	0.97	1.35	3.33	0.04	6
14	banha	3.86	0.49	0.62	0.08	5
15	banha	2.98	0.46	0.82	0.08	4
16	banha	3.21	0.46	0.78	0.08	5
17	kafr Shukr	3.66	0.34	0.44	0.01	4
18	kafr Shukr	4.68	0.27	0.67	0.02	6
19	kafr Shukr	4.45	0.46	0.64	0.01	6
20	kafr Shukr	5.79	0.35	0.36	0.01	7

(1 *): low degree of contamination (CD < 8); (2 *): moderate degree of contamination (8 ≤ CD < 16); (3*): considerable degree of contamination (16 ≤ CD < 32); (4 *): very high degree of contamination (CD > 32).

(1): low contamination (CF < 1); (2): moderate contamination (1 ≤ CF < 3); (3): considerable contamination (3 ≤ CF ≤ 6); (4): high contamination (CF > 6).

Contamination factor (CF) and contamination degree (CD) were evaluated for the surface soil of the study region to evaluate the pollution load relating to anthropogenic contamination. The results of CF values Table (5) were classified into four classes according to Sherif and Atwany (2019)[30]. The contamination factors were calculated for (CU, CD, NI, ZN) in PM all samples, where they showed that The CF of Cu showed moderate contamination in all samples, except in samples 13 which represent (winter in Banha) show low contamination factor. The CF of ZN showed low contamination factors in all samples. The CF of Ni showed low to moderate contamination factor in all samples except (samples 1 and 13) show high contamination factors (3.27, 3.33) in winters of Shoubra ELkhaima and Banha. The contamination factor in all samples was highly contaminated with Cd at all samples (6 ≤ CF) except (samples 5,9 and 15) show moderate contamination (1 ≤ CF < 3); (1.99, 1.83 ,2.98) only sample13 show low contamination factor (0.97) winter in banha.

✓ ***Contamination degree (CD)***

values were assessed as the sum of all contamination factors of the detected metals in surface soil and classified into four classes according to Sherif and Atwany (2019) [30] (Table 5). Samples showed low degree of contamination (CD < 8); in all sites, except in Shoubra El Khima CD showed a moderate degree of contamination (8 ≤ CD < 16) at all seasons except in summer in samples no.1,2,4.

Index of geo accumulation (Igeo)

Table (6)**:** Geo-accumulation index (I_{geo}) classification.

No.	location	Cd	Cu	Ni	Zn
1	Shoubra El khima	5.7	2.5	4.5	0.6
2	Shoubra El khima	6.2	-0.3	1.9	-1.1
3	Shoubra El khima	5.2	1.6	2.7	-0.6
4	Shoubra El khima	5.9	1.2	2.3	-1.3
5	Obour (1)	3.7	1.3	2.5	0.5
6	Obour (1)	5.2	1.3	3.0	-1.7
7	Obour (1)	5.0	2.2	2.9	-0.8
8	Obour (1)	5.4	-0.1	1.1	-3.6
9	Obour (2)	3.6	2.6	4.3	0.6
10	Obour (2)	5.3	1.0	2.5	0.1
11	Obour (2)	5.0	2.2	3.3	0.5
12	Obour (2)	5.2	1.1	2.9	-2.1
13	banha	2.7	3.2	4.5	-2.0
14	banha	4.7	1.7	2.0	-1.0
15	banha	4.3	1.6	2.5	-0.9
16	banha	4.4	1.6	2.4	-0.9
17	kafr Shukr	4.6	1.2	1.6	-3.5
18	kafr Shukr	5.0	0.9	2.2	-3.1
19	kafr Shukr	4.9	1.6	2.1	-3.5
20	kafr Shukr	5.3	1.2	1.3	-3.5

*(green): practically unpolluted (Igeo < 0); (light green): unpolluted to moderated polluted (0 < Igeo < 1); (green White): moderately polluted (1 < Igeo < 2); (White): moderately to strongly polluted (2 < Igeo < 3); (pink): strongly polluted (3 < Igeo < 4); (light red): strongly to extremely polluted (4 < Igeo< 5); (dark red): extremely polluted (Igeo > 5).

Based on the results of Geo-accumulation Index we found that as shown in Table (6). Seasonal variation of the index of geo-accumulation (Igeo) is calculated for the studied heavy metals. The Igeo values of more than zero propose the anthropogenic origin of the metal's contamination in sample. All sites were practically unpolluted with Zn. while most sites were moderately to strong polluted (2 < Igeo< 3) with Cu. The increased concentration of Ni in some sites emitted from the fuel combustion for urban and industrial activities, higher frequency of stop and start-up of vehicles as well as from the soil and sediments beside the expressway in (samples 1,9,13) Shoubra elkhaima, Banha, obour2 show a strongly to extremely polluted Geo-accumulation index (Igeo) (4 < Igeo< 5)rest samples values were varied from moderately polluted (1 < Igeo < 2) to moderately to strongly polluted (2 < Igeo < 3). On the other hand, all sites ranged from strongly to extremely pollute (4 < Igeo< 5) with Cd except samples no.13, 9, 5 which represent winter in Banha, obour2, obour1 (2.7, 3.6, 3.7) showed values indicate moderately to strongly polluted (2 < Igeo < 3) to (strongly polluted (3 < Igeo < 4). These results could be attributed to local emissions due to human and industrial activities in the urban area and the second category is the natural sources of dust storms (e.g. Khamasin dust storms). The negative values of Cu,Zn according to contamination classification of [32] , indicated that it was not polluted by these metals.

Ecological risk factor (Er)

Table (7): Ecological risk factor (Er) and multiple ecological risk factor (RI)

	Location	Ecological risk factor (Er) Er =Tr × Cf				Multiple ecological risk factor (RI) RI = ∑ Er
		Cd	Cu	Ni	Zn	
1	Shoubra El khima	229.3	4.3	9.8	0.2	244
2	Shoubra El khima	337.6	0.6	1.7	0.1	340
3	Shoubra El khima	167.6	2.2	3.0	0.1	173
4	Shoubra El khima	260.3	1.7	2.3	0.1	264
5	Obour (1)	59.7	1.9	2.5	0.1	64
6	Obour (1)	168.4	1.9	3.7	0.0	174
7	Obour (1)	144.4	3.4	3.5	0.1	151
8	Obour (1)	183.4	0.7	1.0	0.0	185
9	Obour (2)	54.9	4.4	8.9	0.2	68
10	Obour (2)	172.2	1.5	2.5	0.2	176
11	Obour (2)	142.2	3.4	4.4	0.2	150
12	Obour (2)	166.7	1.6	3.4	0.0	172
13	banha	29.1	6.7	10.0	0.0	46
14	banha	115.7	2.5	1.9	0.1	120
15	banha	89.4	2.3	2.5	0.1	94
16	banha	96.4	2.3	2.3	0.1	101
17	Kafr Shukr	109.9	1.7	1.3	0.0	113
18	Kafr Shukr	140.3	1.4	2.0	0.0	144
19	Kafr Shukr	133.5	2.3	1.9	0.0	138
20	Kafr Shukr	173.8	1.7	1.1	0.0	177
	TR	**30**	**5**	**3**	**1**	

Er<40 Low RI<150 Low

40 ≤Er < 80 Moderate 150≤RI<300 Moderate

$80 \le Er < 160$	**Considerable**	**$300 \le RI < 600$**	**Considerable**
$160 \le Er < 320$	**High**	**$RI > 600$**	**High**
$Er \ge 320$	**Very High**		

The ecological risk assessment results of toxic metals summarized in Table (7), showed that the potential ecological risk factor of individual metal values (Er) varied belonging the studied metals in different sites. Er values of Cu, Ni and Zn showed low ecological risk in all sites of the study area. In order to quantify the overall potential ecological risk of observed metals. Ecological risk factor for Cd shows a considerable contamination ecological risk factor ($80 < Er < 160$) to High contamination ecological risk factor ($160 < Er < 320$) in samples of all seasons except those sample no. 5,9 in sites (obour1, obour2) Cd showed low values 59.7, 54.9 low contamination ecological risk factor ($Er < 80$) .

multiple ecological risk factor (RI)

Multiple ecological risk factor RI was calculated as the sum of all calculated risk factors Table (7). RI could characterize sensitivity of local ecosystem to the toxic metals and represents the ecological risk resulted from the overall contamination [30]. RI Values of become lower in winter in all sites, low to moderate Multiple ecological risk factor (RI) only in sample no.2, RI Value is (340) as Considerable pollution ($300<RI<600$).

Wind rose

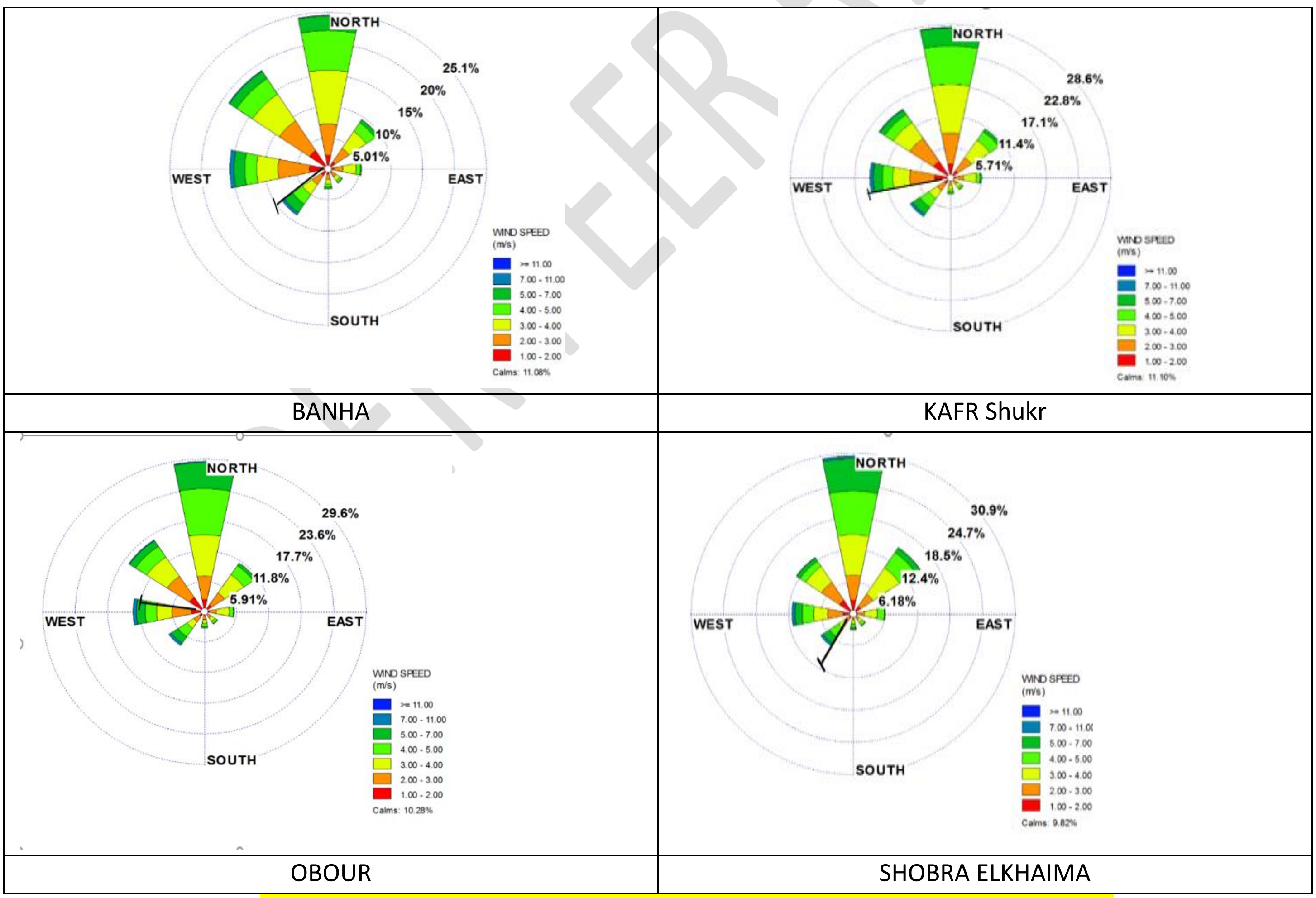

Fig. (3)**: I wind rose representing four year for sampling sites. Show speed and the direction of wind**

Conclusion

Based on the current study, the following can be concluded:

- Dust fall samples collected from five sites of different direction represent collective dust from various sources like industry, surface soil, coal and oil burning, construction activities, motor vehicle and road dust as a dominant source during the study period
- It was discovered that winter and summer months had a lower rate of dust deposition throughout the study area than the other seasons.. On the other hand, fall and spring had the highest rate of dust deposition, it were determined to be the most troublesome seasons with possible adverse health impacts study area's meteorological factors were found to cause variations in pollution levels throughout the year. Therefore, it is essential to put in place suitable measures to lessen the negative impacts of atmospheric sedimentation in the area.
- The ecological risk assessment of heavy metals in the region showed that all sites were practically unpolluted with Cu and Zn, while most of sites were moderately polluted with Ni On the other hand, all sites ranged from strongly to extremely pollute with Cd. These results could be attributed to local emissions of industrial activities.
- according to a contamination assessment based on pollution indices More ecological hazards were posed by Cd than by any other metal, especially in major thoroughfares and industrial dusts.
- Human-related sources of cadmium encompass the production of non-ferrous metals, burning of fossil fuels in stationary sources, waste incineration, production of iron and steel, and the manufacture of cemen There are three primary human-induced sources of terrestrial cadmium: deposition from the atmosphere, the agricultural use of phosphate fertilizers, and the application of municipal sewage sludge as a fertilizer on farmland.(32) the base of the high concentration of cadmium found in rural, urban and industrialized areas The most heavy metals released from vehicles on road are Cadmium (Cd) due to stop and start-up of vehicles and heavy traffic in Shoubra elkhaima and banha,The presence of nickel in the air also derives from the combustion of coal, diesel oil and fuel oil, and the incineration of waste and sewage,Depending on the dose and length of exposure, as an immune-toxic and carcinogen agent, Ni can cause a variety of health effects, such as contact dermatitis, cardiovascular disease, asthma, lung fibrosis, and respiratory tract cancer

Recommendations

- Establish strict regulations and enforcement strategies to manage emissions from industrial plants in the Delta areas. Mandate that industries implement cleaner production technologies and equip themselves with efficient pollution control systems.
- Monitoring and Research: Create extensive air quality monitoring systems throughout the Delta regions to evaluate pollution levels and pinpoint areas of concern. Promote research efforts to gain insights into local pollution sources and formulate specific solutions.
- Advocating for Renewable Energy Solutions: Foster the use of clean energy sources
- . Introduce traffic management techniques to alleviate congestion and decrease vehicle emissions in urban regions of the Delta.

- Improved Farming Techniques: Advocate for sustainable farming methods to reduce agricultural burning as well as the reliance on chemical fertilizers and pesticides, both of which contribute to air contamination. Support the shift towards organic farming practices. . Inform communities about effective waste management techniques to minimize open burning.
- Incorporate green areas and urban woodlands into city design to filter pollutants and enhance air quality. Create zones that prioritize pedestrians and establish cycling paths to decrease dependence on motor vehicles.
- enforcement of current environmental regulations and establish new policies to fill any existing gaps.
- Emergency Preparedness and Response: Create contingency plans and emergency response strategies for serious air pollution events. Issue public health alerts and temporary actions to safeguard at-risk groups during times of high pollution.
- Strengthening the Ministry of Local Development with dust suction and waste disposal equipment Reducing open burning and getting rid of dust accumulated on both sides of the road, which is spread by wind gusts
- Enhancing the environmental awareness for both residents and workers through the governmental and non-governmental organizations

Disclaimer (Artificial intelligence):

This paper has NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) or text-to-image generators have been used during the writing or editing of this manuscript.

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