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

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The southern delta region of Egypt has serious environmental and public health issues due to heavy metal pollution (El-Askary et al. 2021). The air in Qalyubia has higher concentrations of metals including cadmium (Cd), copper (Cu), zinc (Zn), and nickel (Ni) due to the region's intense agricultural practices and industrial discharges. Ring road and the Banha Cairo regional route also traverse the governorate with heavy traffic. The source, distribution, and ecological effects of heavy metals in the south Nile delta region are examined in this study (El-Gamal & Saleh 2016). Dust fall

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sampling allows us to pinpoint important pollution hotspots. The findings show a relationship between increased levels of contaminants and being located nearby industrial sites (Halmy 2019), showing that human activity is a significant source of pollution. We also evaluate the possible hazards to human health, especially for communities (Monib et al. 2024).

Keywords: Heavy metals; contaminants; hazards; communities.

1. 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 the persistence and potential toxicity (El-Askary etal. 2021).

The main source 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 (World Bank 2018). 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 (Egyptian Ministry of Environment 2019). Natural Sources: Dust storms and natural emissions. Efforts to mitigate these sources include stricter regulations, cleaner technologies, and public awareness campaigns (United Nations Environment Program 2017).

1.1 Occurrence and Sources about Heavy Metals

Sources of heavy metals in Egyptian dust include natural mineral deposits, urban and industrial emissions, and agricultural practices (El-Askary et al. 2021) Some activities can release unique trace elements, including metal the production and being processed, nickel and vanadium from combusting petroleum products, copper from copper smelters, zinc from incineration, and lead from lead smelters. (Lowenthal Et al. 2014). 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 deposited them in terrestrial and aquatic ecosystems. The spatial spreading of heavy in dust across Egypt is affected by various factors, particularly the closeness to industrial areas and transportation routes, and agricultural intensification (Ministry of Environment, Egypt 2023).

Heavy metals encompass elements with high atomic weights and toxicity potential, such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As) (Vizuete Zorita et al. 2018). 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 (Elkady etal. 2015). spatial distribution of trace metals in Egyptian dust varies, influenced by proximity to industrial zones, transportation routes, and agricultural intensification (Maas, Samuel et al. 2010).

1.2 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” (Ministry of Environment, Egypt 2023, El-Askary et al. 2021).

Heavy metals pose significant risks due to their tendency to bioaccumulate. Bioaccumulation refers to the gradual buildup the chemicals within a living being through time, especially comparison with the environmental concentration of those chemicals. 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 cause 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.

1.3 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 contaminating soils, with average natural levels around 0.5 mg/kg (Sereni etal. 2023, Sunflower etal. 2014).

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 calculated to evaluate heavy metal pollution using both single and integrated criteria, contamination indices and ecological risk indices were examined. as integrated indices “the potential ecological risk index (RI) and the degree of contamination (DC), were computed in this study, while computed as single indices” the contamination factor (Cf), index of geo-accumulation (Igeo) and ecological risk factor (Er), (Mohammed etal. 2023).

1.4 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 for management of emissions” (Atef et al. 2020). “The study aims to Explain the occurrence, main source, and impacts of trace metals (Cu, Zn, Cd, Ni) in atmospheric dust deposition across Qalyubia Governorate Southern DELTA Egypt, emphasizing their ecological and human health ramifications” (El-Askary et al. 2021).

1.5 Mitigation Strategies and Future Directions

“Effective mitigation strategies are crucial for minimizing the impacts of heavy metals on environment and health 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” (Monib, Abdul et al. 2024).

2. MATERIALS AND METHODS

2.1 Description of the Study Area

QUALYBIA Governorate its location is south of the 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 extend along two banks of Nile delta [Fig. 1]. It includes five residential districts and two industrial zones (CAPMAS 2021). Location situated near the head of the Delta at the eastern Nile region. The administrative regions of Cairo and Giza border it on the south.

Dakahleya and Gharbyah border it to the north, Sharqiyah borders it to the east, and Menofya borders it to the west.

In addition, the greatest industrial cluster is located in Shoubra El Khaima, which includes industries for metal goods, electric appliances, plastics, cars, oil refining, food packaging and processing, and spinning and weaving. (Vizuete et al. 2018).

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 In 2000, there were 5.995.717 people living there. was selected for this study because to its fast development, abundance of large-scale industrial activity, and two industrial districts, both of which are south of the city. There are several kinds of industries, the majority of industrial activities.

QUALYBIA Governorate has an arid [a hot dry climate. semiarid conditions prevailed in summer, in the area investigated, only in the winter season rainfall occurs, from November to April; humidity 58%, the temp.is between 35°C: 42°C in summer and the temperature winter is between 9°C :23°C (http://www.qaliobia.gov.eg).

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 (http://www.qaliobia.gov.eg).

2.2 Method

Samples were taken from different five sites, Table 1. samples were collected show dust that was deposited from the ambient air in glass jar (17 cm height and 8 to9 cm diameter) during 30 days in period from (Dec. 2018 to Nov. 2019). The selected sampling sites were having different pollution levels originating from the human population, traffic den- sites, heavy traffic, economic units that produce pollutants from different industrial activities.

Fig. 1. Selected monitoring sites (source: Google Earth)

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 Elkhaima	Industrial-traffic	31˚23˝73˝	30˚12`20˝
3	Obour (1)	Urban	31˚26`28˝	30˚47`51˝
4	Obour (2)	Urban	31˚45`50˝	30˚21`59˝
5	Kafr.Shukr	Rural	31˚25`63˝	30˚25`64˝

The Microsoft Excel 2007 was used to perform All statistical analyses. Using Stat soft statistical package, STATISTICA for Windows, Copyright Stat Soft, and Inc.

2.3 Sampling of Total Deposited Matters

Site Selection: Five locations were chosen for monitoring dust fallout. every area was monitored for a month during every season. The following are specifics of the chosen locations: Table 2: To measure the dust fall, place a dust fall cylindrical container on a stand at least 1.2 meters away from the support surface. The technique and methodology utilized for dust fall monitoring are detailed in the section that follows.

Dust Fall Collector: Dust fall stations were fixed on tripods that 1.3 meters high to avoid wind eddies which picked up the collection of dust. The container was replaced, for 30 days during the sample period, the collectors were exposed to the atmosphere. Dust fall content was dried to a consistent mass at 105°C, weighed, and the amount of dust fall was calculated in μg/m2. month, as depiced in detail in Fig. 2.

2.3.1 Total heavy metal digestion

atomic absorption spectroscopy analysis used to digestion of dust samples for by placing 0.5 g of the sample in a covered Teflon beaker with a combination of high purity HNO3 (2.5 mL) and percholoric acid HClO4 (2.5 mL) to prevent the loss of Cd and Pb. The beaker was left at room temperature for the whole night. One milliliter of HNO3 was added after the solution had been slowly evaporated to dryness. It was then diluted with 0.1 N HCl and diluted bi-distilled water to extract the residue, which was then filtered through Whatman prewashed filter paper and diluted with 1% HNO3 in a 25-milliliter polyethylene container.

2.3.2 Soluble Heavy Metal (Available) extraction

A magnetic stirrer was used to agitate10 mL of 0.1 M sodium acetate (0.1 M NaOAc) and 1 g of dust material for 24 hours in the dark in order to extract in plastic tubes the soluble heavy metal (available). Centrifugation, filtering (0.22 um pore size), and acidification with 65 vol – % HNO3 (BDH, HNO3 super pure). For both the available and total heavy metal processes, blank solutions were produced for the extract using the same process as for the actual dust samples.

2.3.3 Ecological risk assessment of heavy metals

air contamination and pollution are identifying by using Many Different factors. Some of these factors are described in following sections:

Fig. 2. Dust fall collector model

Geo-Accumulation Index (I_{geo}): (I_{geo}) was generally used to quantify the manmade contamination in surface soil as introduced by Muller (1981), Forster etal., 1993, Loska etal., 2003, Lu etal., 2009; 2010, Gowd etal., 2010 and Manoj etal., 2012. This indicator compares current concentrations with background levels to assess the levels of pollution. (Table 6) (Turekian et al. 1961, Bradford et al. 1996, Tang et al. 2010). by Equation (*a):

$$(I_{geo}) = \log2 [C_n /1.5 B_n] \quad (*a)$$

where C_n was the metal concentration in sample and B_n was the background concentration, 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 considered as the background concentrations for metals (Taylor and McLennan 1985). Igeo values are classified into 7 classes According to Muller (1981).

a) : practically “unpolluted “(Igeo < 0).
b) : “unpolluted “to “moderated “polluted (0 < Igeo < 1).
c) : “moderately “polluted (1 < Igeo < 2)
d) : “moderately “to “strongly “polluted (2 < Igeo < 3).
e) : “strongly “polluted (3 < Igeo < 4).
f) : “strongly “to “extremely “polluted (4 < Igeo< 5).
g) : “extremely “polluted (“Igeo“> 5).

Contamination Factor (CF) and Contamination Degree (CD): to assess the pollution load of deposited dust with respect to heavy metals The CF and CD are used. The CF for each metal is calculated by Equation (*b) (El-Gamal and Saleh 2016) :(Manoj and kumer 2012), (Mohammed et al. 2023).

$$CF = C\ \textbf{metal}/C\ \textbf{background} \quad (*b)$$

where CF is the contamination factor and C_{metal} is the concentration of metal in sample dust. $C_{background}$ is the background value for the metal. (CD) is a summation of all contamination factors for samples by Equation (*c), and n is the number of metals (Loska et al., 2003; Mohammed et al., 2023).

According to Nasr et al., 2006; Rastmanesh et al., 2010; Mmolawa etal., 2011; and Sherif and Atwany, 2019, The CF and CD were classified into four groups (El-Gamal & Saleh, 2016; Mohammed et al., 2023).

as shown in Table 5.

$$CD = \sum (CF_1 + CF_2 + CF_3 + CF_4 ...CF_n) \quad (*c)$$

Ecological risk factor (Er): (Hökanson 1980) suggested An ecological risk factor (Er) to quantify the potential ecological risk of a contaminant by

$$Er = Tr \times Cf \quad (*d)$$

Where “Tr “was the “toxic-response factor “of sample, and Cf is the “contamination factor”. (Hökanson 1980) Suggested that the “Tr “values of “Cu, Cd, Ni and Zn “are (5, 5, 3, and 1), respectively. The following terms are used to describe the risk factor (“Er “< 40) as a “low potential “ecological risk;(40 < “Er “< 80) “Moderate potential “ecological risk;(80 < “Er “< 160) as a “Considerable potential “ecological risk; (160< “Er “< 320) as a “High potential “ecological risk; (“Er “> 320) as a “Very High potential “ecological risk.

3. RESULTS AND DISCUSSION

3.1 Dust Fall Deposition Rate

Table 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 samples.

The highest rates of dust deposited were recorded in autumn 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. (El-Bady 2014). 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.

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

	Shoubra Elkhaima	Obour (1)	Obour (2)	Banha	Kafr Shukr
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

Heavy Metals Concentrations in Particulate Matter (PM10):

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

Site	Statistical analysis	Cd	Cu	Ni	Zn
Shoubra 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

Shoubra Elkhaima has higher annual mean concentrations of the most of heavy metals. The findings indicated that the concentrations of heavy metals were observed in the following order: Ni (0.03 mg/m^3) > Cu (0.22 mg/m^3) > Zn (0.32 mg/m^3) > Cd (7.46 mg/m^3). These higher concentrations attributed to local emissions of industrial activities in "Qalyubia governorate region Shoubra El-Khima "which located close to the moasasaa power station, and near various industrial activity with incomplete burning of fuel. Lowest annual mean concentrations of heavy metals in the ambient air (PM_{10}) are in Banha. The results showed that the heavy metal concentrations found were arranged as following: Ni (0.03 mg/m^3) > Cu (0.10 mg/m^3) > Zn (2.07 mg/m^3) > Cd (2.48 mg/m^3). This result attribute to unpaved roads and various human's activities.

Contamination Factor (CF) and Contamination Degree (CD): to evaluate the contamination load relating to manmade pollution. The results of (CF) values Table (5) were classified into 4 terms according to Sherif and Atwany (2019). The contamination factors were calculated for (CU, CD, NI, ZN) in PM of all samples, they showed that (CF) of copper showed a "moderate "contamination in all samples, except in samples no. 13 which represent (winter in Banha) show a "low "contamination factor. (CF) of Zinc showed a "low "contamination factors in all samples. The (CF) of Nickel showed a "low "to "moderate "contamination factor in all samples except (samples 1 and 13) show a "high "contamination factors (3.27, 3.33) in winters of Shoubra ELkhaima and Banha. The contamination factor in all samples was highly contaminated with Cadmium 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): "CD "Values describe as summation of all contamination factors of the metals in samples and classified into four classes according to (Sherif and Atwany 2019) (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.

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 - contamination (CD < 8); (2 *): moderate degree - contamination (8 ≤ CD < 16); (3*): considerable degree - contamination (16 ≤ CD < 32); (4 *): very high degree - 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)*

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 results of "Geo-accumulation "Index we found that as shown in Table 6. Seasonal variation of "geo-accumulation" index (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 samples. All sites practically "unpolluted" with (Zn). while most sites were "moderately" to "strong" polluted (2 < Igeo< 3) with (Cu). The increasing concentration of (Ni) in some sites which emitted from the combustion of fuel in urban and industrial activities, higher frequency of stop/start-up of vehicles also 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" polluted (4 < "Igeo"< 5) by 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 natural sources as dust storms (e.g. Khamasin dust storms). The negative values of "Cu and Zn" according to contamination classification indicated that it was unpolluted by those metals (El-Bady 2014).

"**Ecological Risk Factor** " **(Er):** The assessment of ecological risk resulting by toxic metals summarizes in Table 7, showing that the" potential ecological risk" factor of individual metal values (Er) varied belonging the study metals of different sites. (Er) values of "Cu, Ni and Zn" showed "low "ecological risk in all studied areas. In order to calculate the total 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) calculating as the summation of all calculated risk factors Table 7.

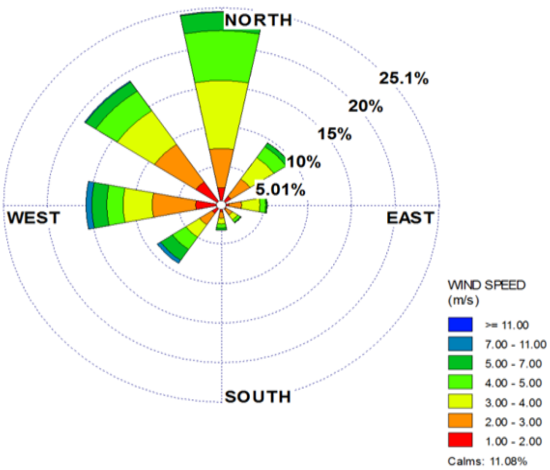
(RI) characterized the ecosystem sensitivity to the toxic metals and represents the resulting "ecological risk" from overall contamination (Sherif and Atwany 2019). RI Values of become lower in winter in all sites, "low" to "moderate" Multiple ecological risk factor (RI) only in sample no.2, RI Value is (340) as "Considerable" pollution (300<RI<600).

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

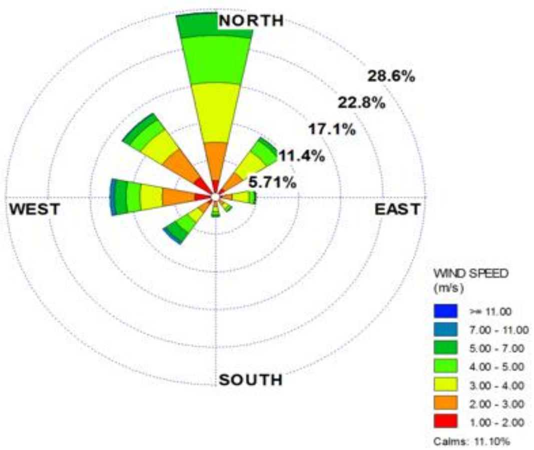
Location		**"Ecological risk factor" (Er) Er =Tr × Cf**				**Multiple ecological risk factor (RI) RI = ∑ Er**
		Cd	**Cu**	**Ni**	**Zn**	
1	Shoubra El khima	229.3	4.3	9.8	0.2	244
2	Shoubra El khima	337.6	0.6	1.7	0.1	340
3	Shoubra El khima	167.6	2.2	3.0	0.1	173
4	Shoubra El khima	260.3	1.7	2.3	0.1	264
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 <Er < 160	**Considerable**	**300<RI<600**	**Considerable**
160<Er < 320	**High**	**RI>600**	**High**
Er > 320	**Very High**		

Wind Rose:



BANHA



KAFR Shukr

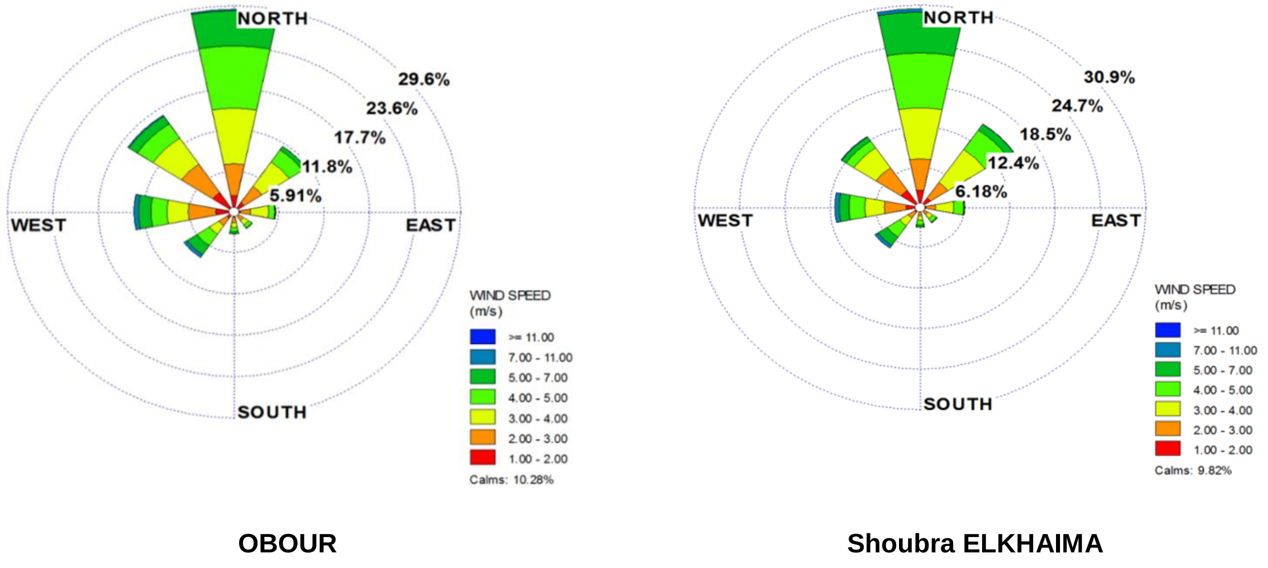


Fig. 3. Wind rose representing 5 years for sampling sites. Show speed and the direction of wind

4. CONCLUSION

Based on this current study, can conclude the following:

- Dust fall samples collected from five sites with different sites represent collective dust from various sources like" industry activities, residential, rural and heavy traffic "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 area of study than other seasons. But, fall and spring had the highest rate of dust deposition, it was 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.
- ecological risk of heavy metals in those regions showed that all locations are nearly free of (Cu) and (Zn) contamination, while most of it are moderately polluted with (Ni), while contamination level of (cd) varied from extremely contaminated to strongly polluted. Those results might 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 cement There are three primary human-induced sources of terrestrial cadmium: deposition from the atmosphere, use the agricultural phosphate fertilizers, and the application of "municipal sewage sludge" as a fertilizer on farmland (32) The base of the high concentration (Cd) found in rural, urban and industrialized areas. The most heavy metals released from vehicles on road are (Cd) due to stop/start-up of vehicles and heavy traffic in Shoubra elkhaima and banha, The presence of (Ni) in the air also derives from coal combustion, diesel oil ,fuel oil, and waste and sewage incineration, Depending on the dose and length of exposure, as an" immune-toxic and carcinogen agent", a variety of health effects can caused by (Ni) as " contact dermatitis ", "cardiovascular disease ", "asthma ", "lung fibrosis ", and respiratory tract cancer.

5. 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. 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.

- Monitoring and Research: Create extensive air quality monitoring systems throughout the
- 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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