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Characterization of Minerals and Health Impact of Metals in Dust Storm Fallen on Baghdad, Iraq

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Abstract: In Iraq, dust storms have increased drastically over the past decade due to desertification, dryness, and potential outcomes of climate variation. The present study determined the material composition of the dust storm that attacked Baghdad on the 14th of April 2022. Techniques like XRD, SEM, FTIR, and BET were used to identify the structure, particle size and mineral constituents. The study was performed by collecting dust storm samples from different areas of Baghdad. Experimental results showed that the particle within the highest range was between 186 nm and 248 nm and the mean diameter was 217 nm in which the maximum intensity was determined. The identified elements (Si, Ca, Ti, C. Al, Fe, Mg, Cu, and S) and nonmetallic elements C and O with different average weight percent while calcium and silicon were the most abundant elements. Assessment of their toxicological impacts on human health particularly on human eyes has also been done. Eye maladies were the most usually considered health status in all source locations of Baghdad city, ranging from 39.0% to 42.0%. Moreover, respiratory (27.2%–31.4%) and allergic skin (6.6%–9.5%) diseases were the second and third most usually investigated cases, respectively.

Key words: Soil dust, minerals, storm, characterisation techniques, particle size distribution.

Introduction

Dust is rigid airlifted particles that scale 100 to 30000 nanometers. Dust is generally the rigid particles by actions such as storming, smashing, transporting, braking, exploding, or grist varied substances. The substances could be organic or inorganic such as metals, coal, wood, rock, and grain. Dust of size less than 10 micrometers can enter profoundly into the alveolar sacks of the lungs and eyes.

The expression sand storm is utilised generally in the situation of desert sandstorms, specifically in deserts, or areas where sand is a predominant soil sort than rock with fine particles concealing vision. The expression dust storm is usually utilised when finer particles are blown in lengthy ranges, specifically

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when the dust storm impacts urban zones (Sissakian et al., 2011). In order to develop the operational component of SDS-WAS (**S**and and **D**ust **S**torm -**W**arning **A**dvisory and Assessment **S**ystem) and to transfer the experience gained in the research phase to the operational services, the Barcelona Dust Forecast Centre was opened in February 2014, following the WMO (World Meteorological Organization) decision that dust prediction was mature enough to implement operational services. Figure 1 depicts a forecast of dust optical depth at 550 nm released by the Barcelona Dust Forecast Centre on 29 March 2014 at 12 UTC.

Countries found in barren and semi-barren bands like Iraq are interested in dust storm occurrence. In Iraq, dust storms have largely risen during the previous decade due to desertification, dryness, and potential outcomes of climate variation. Dust and sand storms are a permanent issue in Iraq and other adjacent countries, but they are most common through the time period of spring and summer because of the vigorous winds that identify the atmospheric condition through the seasonal transmission of spring-summer (Kobler, 2013). In particular, sand storms take place as powerful de-moistured storms (that predominately join completely-defined chilly foreheads) circulate these particles. Both dust and sand elevate before and at the back of the chilly forehead because air currents proceed to be more potent beyond the forehead than before it (Aood et al., 2017). This seasonal tendency may be identified as a collection of two different climate modes, the semi-tropical flow current thrusting overhead south of the Arabian Semi-isle and an arctic front flow current dropping off the European continent. As the two modes arrive in the adjacent vicinity, it makes a considerably extra energetic climate than is commonly set within this area, particularly the powerful northwesterly air currents (Varoujan et al., 2013). Figure 2(a, b) are satellite photographs displaying a dust storm enveloping the western south portion of Iraq and proceeding toward Baghdad arriving from neighbouring western regions of Iraq. Figure 2c represents a snapshot of storm dust striking an Iraqi village in Al-Anbar province at the western of Iraq. Figure 3 depicts a bar chart of the total frequency of dust storms annually in Iraq. Moreover, Figure 4 displays

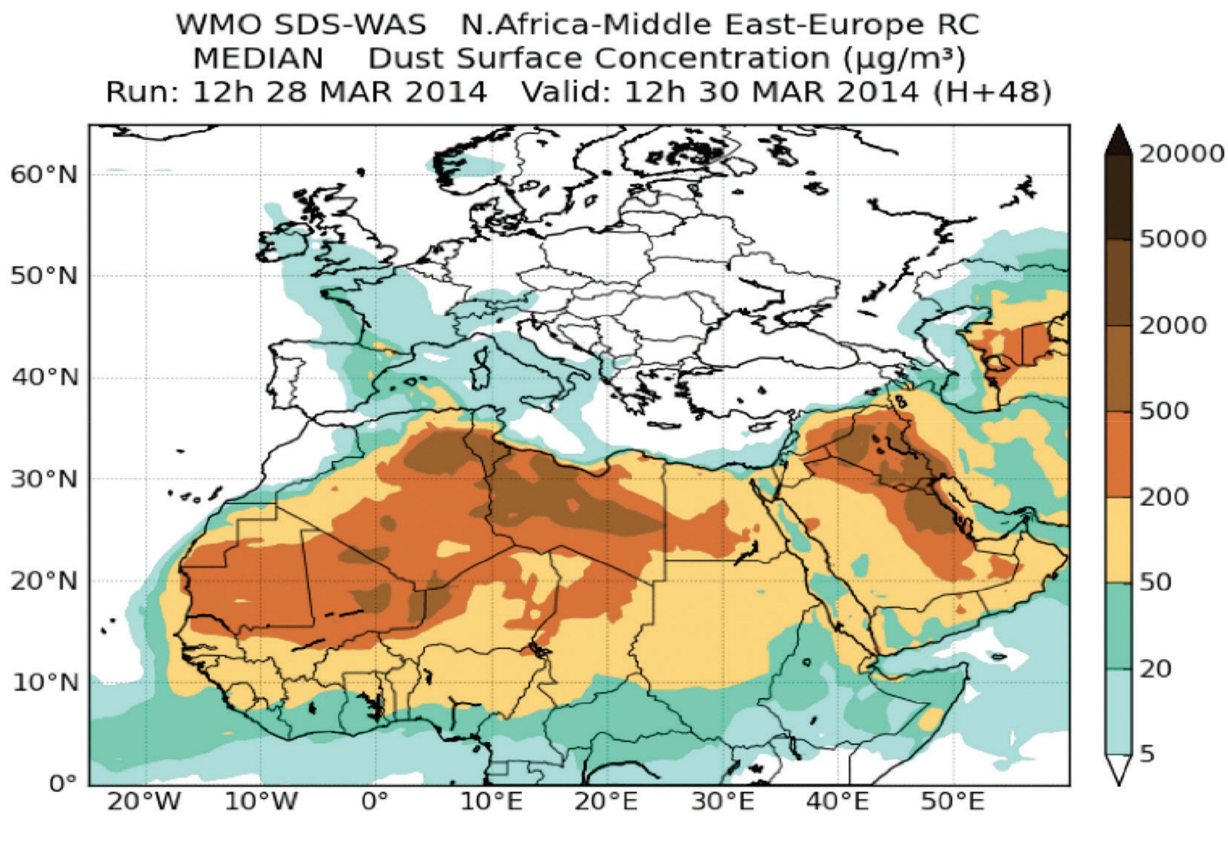


Figure 1: Forecast of dust optical depth at 550 nm released by the Barcelona Dust Forecast Centre on 29 March 2014 at 12 UTC (WMO SDS-WAS).

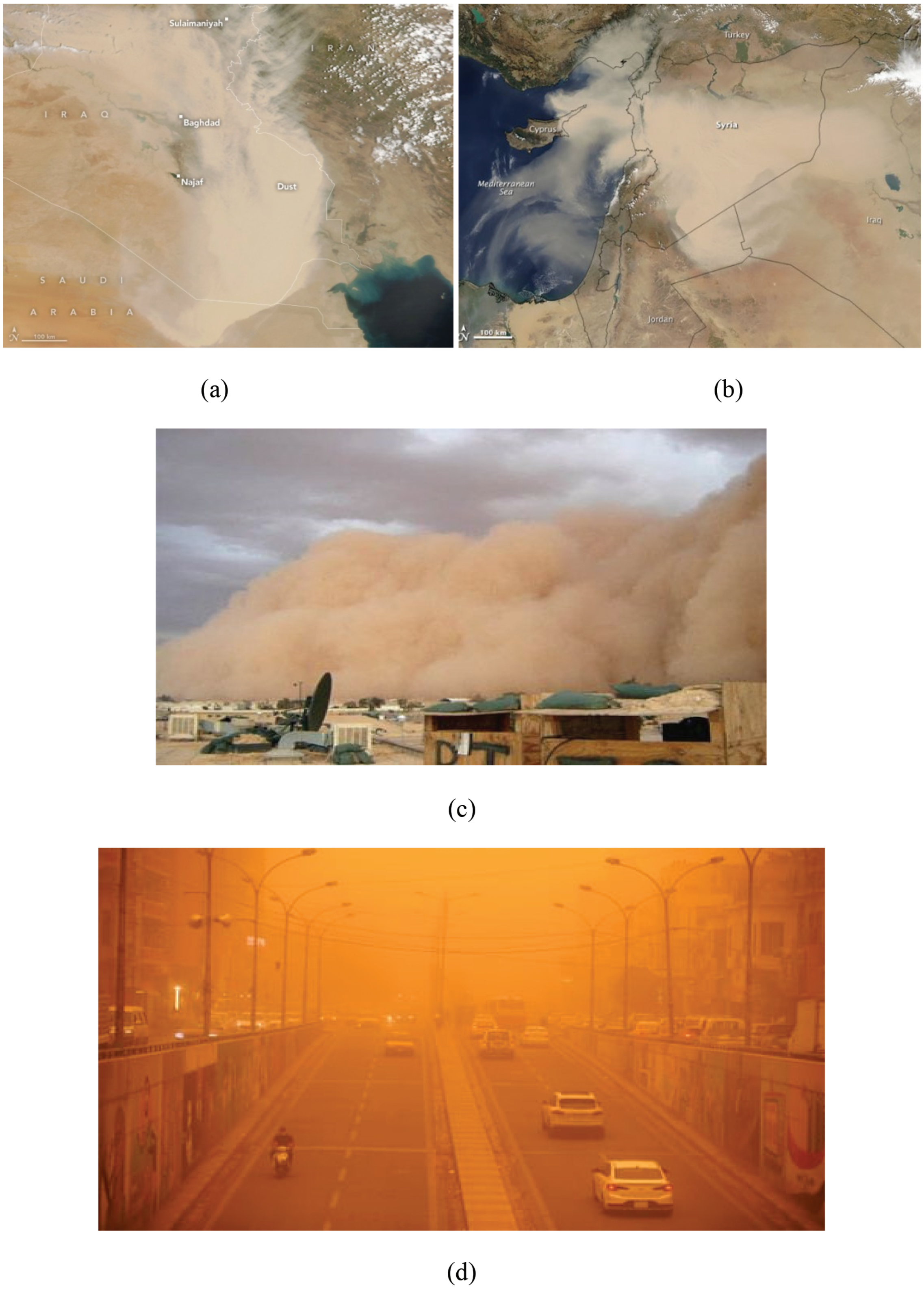


Figure 2: Different images of dust storms striking Iraq. (a) and (b) are satellite photographs displaying a dust storm covering the western south portion of Iraq and proceeding toward Baghdad (April 14, 2022) (https://earthobservatory.nasa.gov/images/149695/dust-storm-in-iraq; (c) Snapshot of storm dust striking an Iraqi village in Al-Anbar province, (d) Dust settled across streets and vehicles and seeped into homes in Iraq's capital Baghdad (https://www.gettyimages.com/photos/sand-storm-hits-baghdad).

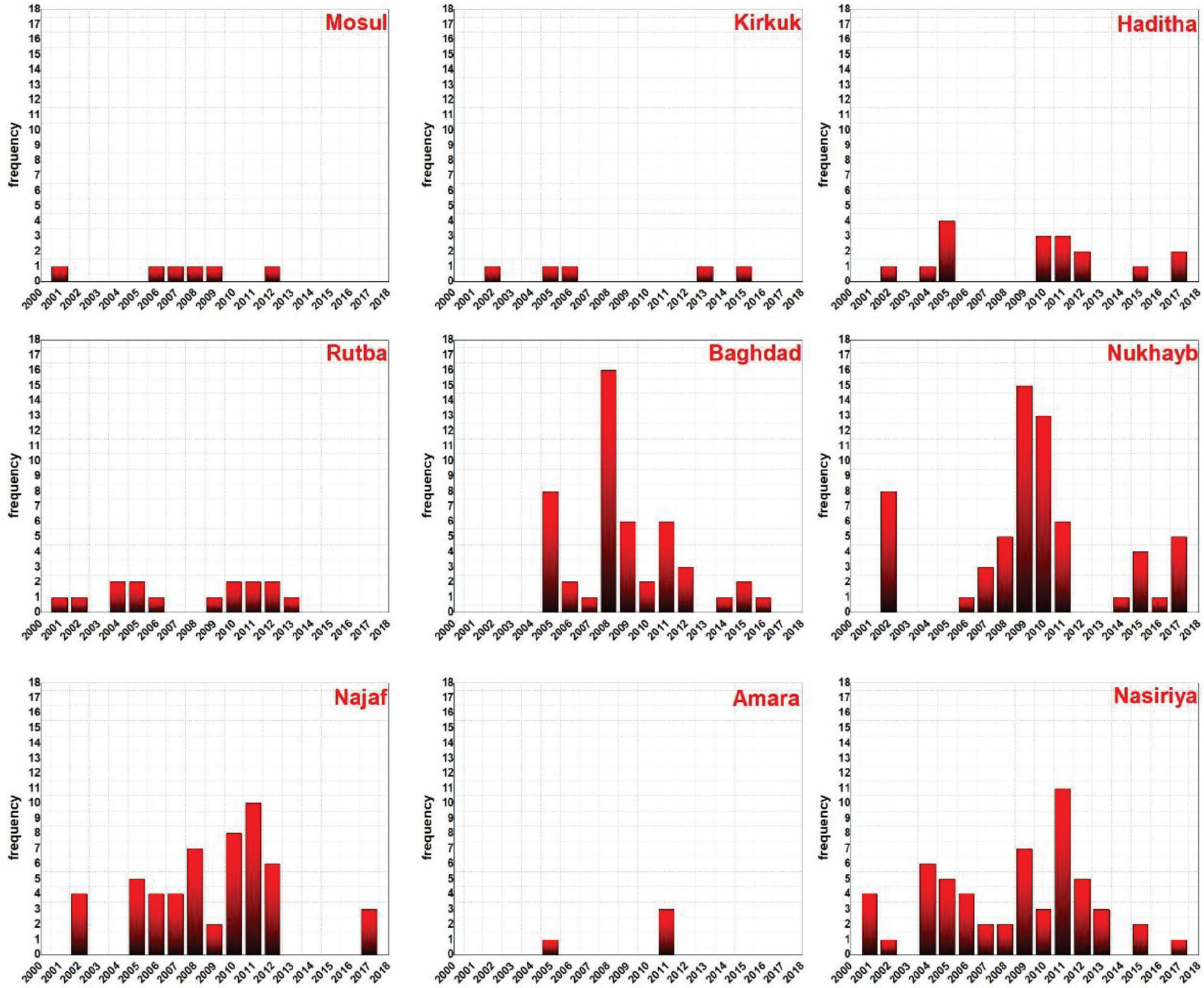


Figure 3: The overall yearly number of Iraq dusty storms in different Iraqi locations (2001-2017) (Ibrahim et al., 2019).

the locative variation of the annual mean frequency of dust occurrences. The dust appearance is high in the southern and central portions of Nasiriyah, Basra, and Baghdad followed by the Mosul sector neighbouring the Syrian sector.

The unparalleled natural and artificial physical features and human interference at the zone also participate in the frequency and flux of sand storms in the considered region. The normal funneling of huge air clusters by the elevated hills in Turkey and Iran joined with the high hills in KSA facilitates to directing of air through Iraq into the Arabian Gulf. Moreover, much Iraqi land consisting of marshes has been emptied for farming or industriously prohibited water by dams upstream. This enhances dust as the air current raises arid alluvium from the bottoms of marsh. The prime reason for promoting a dust storm is stated by Squires (2007) who reported that "As the force of wind proceeding over freely caught particles grows, sand particles first begin to oscillate. The gusty winds frequently pound the land, decomposing it into minimal-size particles of dust, and then start to tour in suspension mode through the air. At greater wind velocities, which makes the tiny particles hang up, there will be a community of dust particles stirring by a number of techniques: suspension, turbulence, and crawl". Anyhow, a dust storm is the outcome of numerous parameters, which extend to various provincial countries. Decades of unsuitable farming work, bad administration of water reservoirs and climate variation keep participating in decreasing vegetation covering, desertification and dryness, which straightway participate in the rising regional dust storm trouble. Desiccations and arid situations support the decay of soil particles and wind

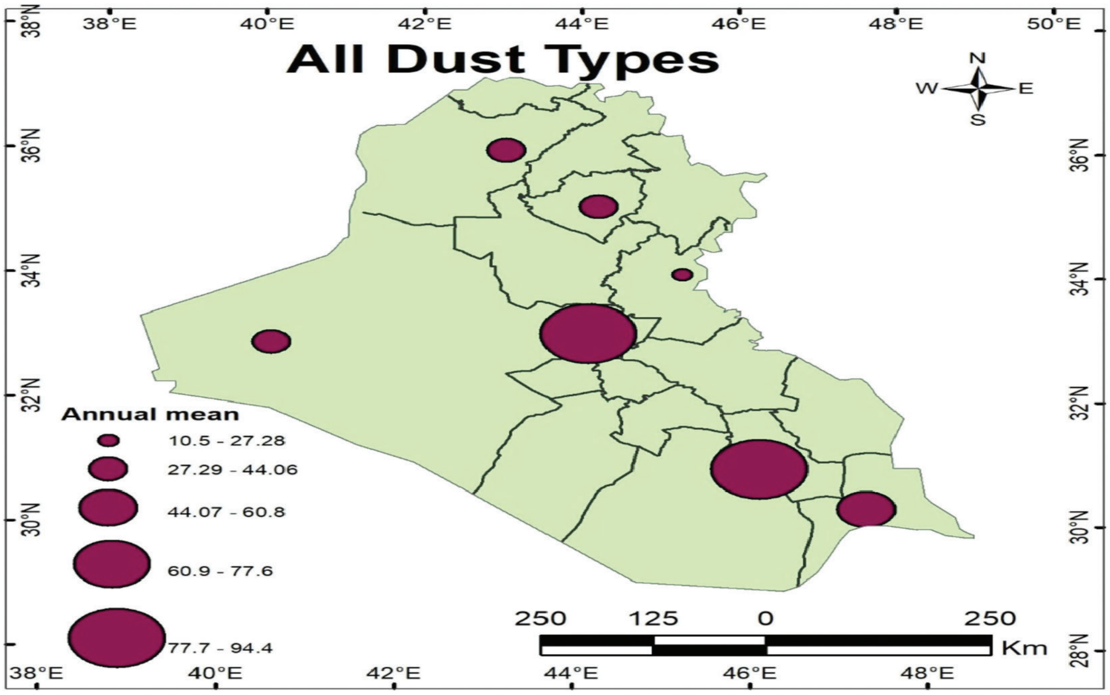


Figure 4: The yearly average frequency of all Iraq dust incidents over 1980–2015 (Ali and Jones, 2020).

shares in the evolution of dust storms (Christian et al., 2021). Choobari et al. (2014) presented an overview of the distribution of mineral dust around the globe, its direct, semi-direct and indirect effects, as well as its impacts on the dynamic state of the atmosphere have been discussed. The authors showed that mineral dust aerosols play a key role in the Earth's climate system and hydrological cycle through their radiative and cloud condensation nuclei effects. Hemati and Rahimi (2020) studied the concentrations and pollution grades of heavy metals like cobalt, chrome, lead, copper, manganese and zinc in road dust gathered from Hamedan town, Iran utilising three pollution evaluation techniques. The authors found that the average amounts of zinc, copper, lead, manganese, chrome and cobalt in the dust specimens were 190, 64, 62, 380, 35 and 20 mg/kg, respectively.

Alharbi (2021) conducted an experimental and analytical study of the chemical contents of dust storms in agrarian zones of dried soil in the Kingdom of Saudi Arabia. The author gathered specimens of settled dust from 18 locations in Al-Qassim province having a population of about 1.4 million. Alharbi (2021) reported that the content of the gathered specimens consisted of heavy metals like As, Cd, Co, Cr, Cu, Pb, Ni, Ba and Zn.

Much work has been done to study the geographical distribution of storms in Iraq and around the area. Much less work has been published on experiments to identify the structure of dust storms and their impact on human health, so it was felt that there was a need for further work to fill the gap along this line. Accordingly, the objectives of this study are to characterise the dust of the Iraqi storms and to highlight the pharmacokinetic mechanisms together with toxicological effects on human health and eyes when they enter the human eyes by polluted sands and dust.

Experimental

Dust Sampling

The dust samples were collected from different areas of Al-kara city on the western side of Baghdad during the period storm attack Iraq on the 14th of April 2022 which lasted for 3 days. The dust material from the storm was collected on 10 tissue materials placed at a height of 6.0 m in roadside and land areas. Then tissue specimens were rinsed in demineralized water and the sediment dust was then dehydrated at 110 °C in the oven and utilized for test. All of the specimens from different areas were mixed carefully and samples were taken for testing against minerals and inorganic metal components using XRD, SEM, FTIR and particle size distribution by BET techniques.

Results and Discussion

In order to determine the range of particle size of the dust material the particle size distribution was measured using the BET technique, as shown in Figure 5, the result shows the particle size distribution as a function of their intensity within the bulk of the sample under test, it's clear that the particle within the highest range illustrated between 186 nm and 248 nm and the mean diameter 217 nm in which the maximum intensity was determined.

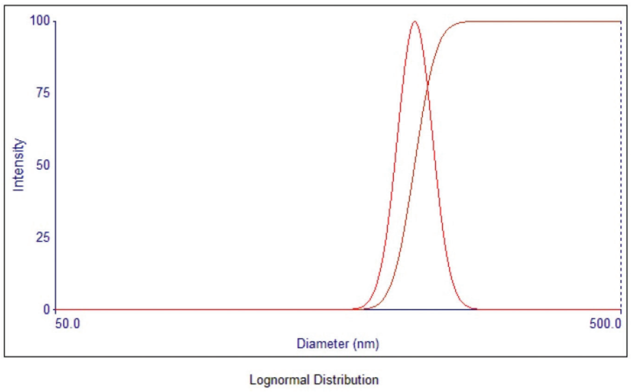


Figure 5: Lognormal particle size distribution of dust sample.

The main reason for the variation in particle size is due to the nature of wind storms, their force, and their velocity. In such cases as the strength of the air current going over free particles grows, particles of sand initially begin to vibrate and then jump. As they frequently hit the soil surface, they disengage and divide into minimal particles of dust, which then start to move in the suspension. As air current accelerates above that, causing minor suspension there will be a group of dust granules moving by a scope of pathways: suspension, turbulence-moving, and crawl (Christian et al., 2021). Also, the vibration of suspended particles causes them to strike the particles with each other with high energy leading to the splitting of the large particles into small nanoscale particles. On the other hand, the surface structure of the dust specimen was analysed by scanning electron microscope (SEM), and the result is shown in Figure 6.

The result of SEM shows different mixed materials, such as dried clay particles, sand particles, and plant fragments. Material like clay seems to be larger than sand particles, which may be due to their tendency to accumulate with each other. On the other hand, we found it difficult to recognize some biomaterials such as microorganisms within the present analysis facilities which are considered outside the scope of this research at present. X-ray fluorescence technique was used to study the chemical composition of the dust specimen, the result shown in Figure 7. The result exhibited a well-defined peak related to some metallic elements and nonmetallic elements within the structure of the dust material. The identified elements (Si, Ca, Ti, C. Al, Fe, Mg, Cu, and S) and nonmetallic elements C and O with different average weight percents are listed in Table 1. Calcium and silicon were the most abundant elements.

Table 1: The chemical composition and average weight % of dust specimen

Element	*Average Weight (%)*	*Element*	*Average Weight (%)*
O	40.89	Al	5.45
Si	20.72	Fe	4.97
Ca	10.43	Mg	3.03
Ti	8.44	Cu	0.22
C	5.84	S	0.0

Infrared spectroscopy was used in this study to identify the structural properties of the storm dust. The

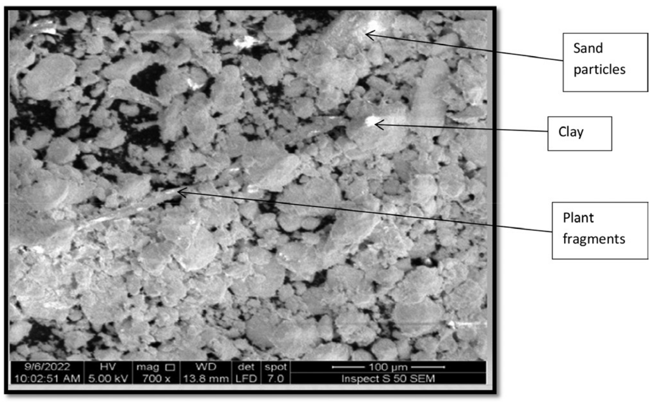


Figure 6: SEM image of dust sample collected from different areas in western bank (Alkarkh side) of Baghdad city.

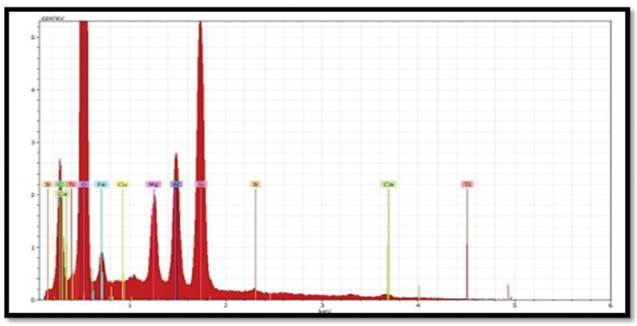


Figure 7: Energy dispersed XRF result of dust specimen.

FTIR image (see Figure 8) was obtained by the FTIR spectrometer model (Shimadzu 8400 S, Japan). The band peaks at 777 cm^{-1} represented the Si-O symmetric bending and Si-O stretching. The band peak at 872 is due to CO_3 stretching and C=O stretching of Calcite. The peaks observed at about 1007 cm^{-1} are of strong stretching of Si-O due to Nacrite. The peak at 3396 cm^{-1} shows the presence of montmorillonite which was assigned to H-O-H stretching mode vibration.

The XRD test was used in this work to study the crystal structure of the storm dust. Figure 9 presents the X-ray pattern of the prepared storm dust. Sharp peaks of the product indicate that it is a crystalline material, other peaks are due to the amorphous structure of other compounds. The observation results show that the dust sample consisted of major mineral materials such as quartz, calcite, asbestos and montmorillonite.

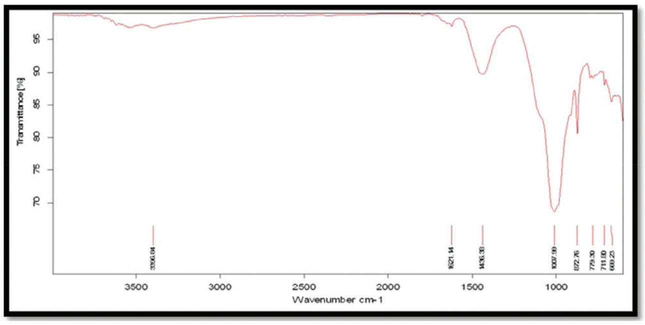


Figure 8: FTIR spectrum of storm dust.

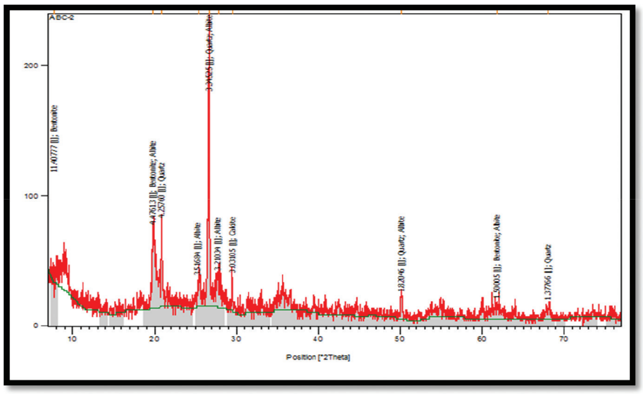


Figure 9: XRD spectrum of storm dust.

Case Study

Effect of Storm Dust on Health Status

Table 2 displays the contributor's characteristics in the present work (age, 30.0 ± 15.0 years). A total of 300 contributors, of different genders, living in Baghdad province were enrolled in this study.

As observed in Table 2, eye maladies were the most usually considered health status in all source locations of Baghdad city, ranging from 39.0% to 42.0% (Table 2). Moreover, respiratory (27.2%–31.4%) and allergic skin (6.6%–9.5%) diseases were the second and third most usually investigated cases, respectively. Other less studied health statuses covered school absence due to sickness, accidents and injuries, cerebrovascular, mortality, and adverse birth outcomes.

Table 2: Effect of storm dust on the characteristics of health status

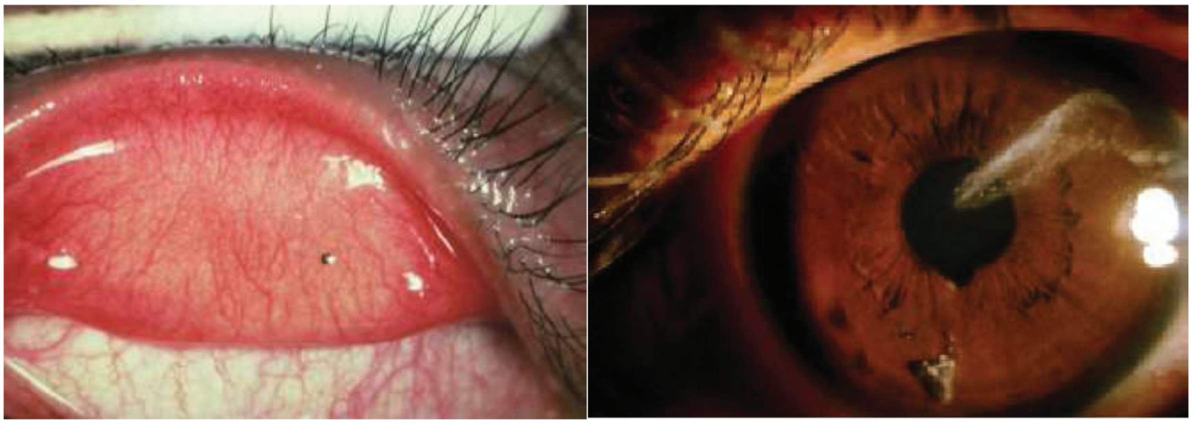
Health Status	*Male (N = 178)*		*Female (N = 122)*	
	n	%	*n*	%
Eye disease	74	(42.0)	48	(39.0)
Respiratory	48	(27.2)	38	(31.4)
Allergic skin	17	(9.5)	8	(6.6)
Cerebrovascular 6 (3.2)	6	(5.0)		
Adverse birth outcomes	0	(0)	6	(5.0)
Accidents and injuries	11	(6.0)	5	(4.0)
Mortality	7	(4.0)	2	(2.0)
School absence due to illness 15 (9.0)	9	(7.0)		

Figure 10 (a,b) shows sample images of the eye (with symptoms) during a dust storm. Figure 10c shows an x-ray image of an intra orbital foreign body. As can be seen in Figure 10, dust particles loaded with heavy metals enter the eye and affect the cornea, aqueous, vitreous, lens, and ciliary body.

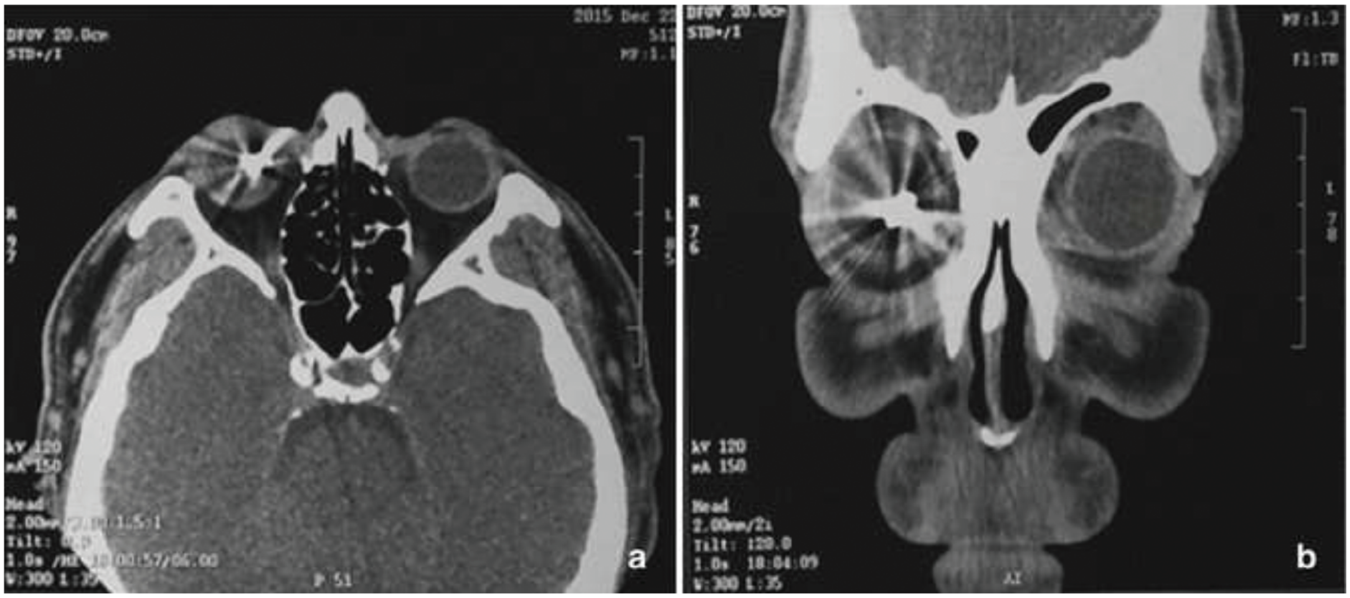
It was reported by the Newsletter of the Iraqi Ministry of the Environment on the 14th of April 2022 that 19 people lost their lives and 121 animals were killed in the 3-day dust storm that struck Baghdad province. This storm of dust gave rise to many various impacts on Economic efficiency, and individual health.

Conclusion

The stormy environment is usually composed of the land, water, atmosphere and biosphere. Environmental contaminants as well as pollutants are chemicals that are present at a higher level in any section of the environment windy weather. The result of the Baghdad storm showed the samples contained a list of metals according to their weight percent in the samples like Ti, Fe, C, Al, Mg, Cu, zinc, and Ca. One of the aims of this work was to highlight the toxicological impacts on



(a) (b)



(c)

Figure 10: Sample images of eye (with symptoms) during dust storm.

human health particularly on human eyes, in such case when very fine particles enter the human eyes organisms cannot be broken down and are non-biodegradable and despite as intracellular granules with insoluble forms for long term storage, then they are classified as dangerous This bioaccumulation cause biological and physiological complications, indeed some metal may cause toxicity as they can interact with DNA and nuclear protein of the cells causing DNA damage leading to apoptosis and carcinogenesis effect Image of foreign body on cornea intra ocular foreign body conjunctival foreign body. The high concentration of heavy metal in the fluid and tissues of human eyes affects cornea, aqueous, vitreous, lens and ciliary body.

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