JOURNAL OF AERONAUTICAL MATERIALS
ISSN: 1005-5053
Vol. 43, Issue-01, 2023
pp. 1522-1535

# ASSESSING HEALTH IMPACT OF SAND AND DUST STORMS & APPLICATION OF ARTIFICIAL NEURAL NETWORK MODELING FOR ESTIMATING THE TYPES OF DUST STORMS IN HILLA CITY, IRAQ

**Abrar F. Deindee[1], Suad M.Al-Fatlawi[1]**
[1] Department of Environmental Engineering, College of Engineering, University of Babylon, Iraq
[*] Corresponding author's e-mail: abrar.falah.engh314@student.uobabylon.edu.iq

## Abstract
Sand and dust storms are common hazardous phenomena that can be observed in many areas in Iraq, particularly in Hilla city. A little amount of work, however, has investigated the hazards of these meteorological phenomena in this particular area. In the current work, this task has been carried out, aiming to understand and assess the impact of dust storm-induced air pollution on the health of Hilla city inhabitants. This has been done using AirQ+ software developed by World Health Organization. The concentrations of particulate matter with a diameter of 10 microns (PM10) and those with 2.5 microns (PM2.5) are usually used to determine the air quality index in the majority of Iraqi cities and it is used here. According to the Iraqi Meteorological Department, six dust storms with known particle concentrations have been recorded in 2022. Comparing that to the record in 2021 in which no dust storms have been observed, it is found that the relative risk of respiratory diseases has increased to 3.395 during dust storm days, resulting in more than 1592 cases to be hospitalized. Additionally, the number of hospitalizations of people with cardiovascular disease has reached 702 cases with a relative risk of 1.801. The results, also, indicated that the health effects of higher concentrations of pollutants are perhaps the main cause of death in some instances. Rain had 100% significance across all parameters, according to ANN model architecture, and normalized importance for input parameters, whereas the air temperature had a lower significance (8%).
**Keywords:** AirQ+ Software, ANN, short term exposure, dust storms, PM2.5, Health Impact.

## Introduction
Sand and dust storms usually occur when many particles of sand and dust are lifted into the atmosphere due to strong winds, coming from bare and dry soils. Tozer and Leys (2013) defined dust events that a wind loaded with total suspended particles greater than 100 µg/m3. Other studies have indicated that dust events may occur when PM concentrations are above 200 µg/m3 or even 150 µg/m3.
Over the past ten years, many studies have laid down the effects of dust on the climate, human health, environment and many social and economic sectors. In general, the biological, chemical and physical properties of suspended dust particles have a detrimental effect on human health when they are inhaled (Zhang et al., 2016; Goudie, 2014).
Air pollution continues to be a serious health risk for people all over the world. Short-term exposure of a concentrated-form of dust, for example, can worsen bronchitis, asthma and other respiratory conditions as well as can alter the heart-rate variability. Long-term exposure is even worse as the inhaled particles may raise the risk of cancer, respiratory disorders and

arteriosclerosis. Lodovici et. al. (2011), on the other hand, suggest that an inflammatory cascade and oxidative stress in lung, vascular, and heart tissue can develop as a result of exposing to a concentrated-form of dust. Further, according to a World Health Organization (WHO), more than 2 million premature deaths per year are related to the consequences of urban outdoor and interior air pollution, including heart and lung disease and respiratory damage caused by the polluted air. People in underdeveloped countries, unfortunately, suffer from more than half of these diseases (WHO, 2006). Accordingly, it is important avoiding dusty air and living in a clean environment for a better health and a proper well-being.

The air pollutants are mainly caused by the particulate matter (PM10 and PM2.5) and gases (e.g. ozone, carbon monoxide, sulfur dioxide and oxides of nitrogen). Measurement of particulate matter can be viewed as a useful parameter to measure air quality (AQ) since it indicates the influence of polluted air on public safety (Abbas, 2021).

Particulate matter (PM10 and PM2.5), in general, is a mixture of particles with liquid droplets suspended in air as a form of particulates. PM10 are particles that have a size of less than or equal to 10 microns and PM2.5 are ultra-fine particles, having a size of less than or equal to 2.5 microns. Particulate matter is released from constructions, smoking, cleanings, demolitions and natural hazards (such as earthquakes and volcanic eruptions). The emissions from industries (e.g. brick kilns, paper and pulp) are also a source of air pollution. According to the Iraqi standard specifications, safe exposure limits are 25 μg/m3 for 24-hour average exposing and 10 μg/m3 for annual average.

There are significant threats to human health from airborne dust. The size of dust particles has a vital role in estimating the potential damage to human health. Only eyes, skin, and nose can be injured by particles larger than ten meters because they are constantly irritated. Also, these organs can develop conjunctivitis, and are more prone to infection. Because small particles (especially PM 2.5) can be stuck in nose, mouth, and the upper respiratory tract of human, they can cause respiratory disorders such as pneumonia, asthma, tracheitis, silicosis, allergic and rhinitis. Furthermore, smaller particles may reach the bloodstream through the lower respiratory tract and impact all internal organs, leading to cardiovascular diseases (Terradellas et.al., 2015).

The incidence of cardiovascular illnesses, lung cancer and death can each rise by 4 to 8% when exposing to PM2.5 concentration of 10 g/m3. In Hong Kong, for example, there is a 2% rise in hospitalization and a 2% increase in mortality from respiratory problems for every 10 g/m3 rise in the average daily PM2.5 concentrations. Elderly people and kids are more susceptible to increases in PM concentrations in general (Bilal et. al., 2019).

Globally, dry and semi-arid regions frequently experience dust storms. This phenomenon, which is caused by strong winds, causes a lot of dust to be raised from the desert floor and reduces vision to less than one kilometre. According to Mehdi et.al. (2014), the temporal frequency of occurrences and their spatial ranges have drastically increased in recent years. The same authors indicate that the dust storms in the Middle East have a substantial impact on the quality of life for residents, visibility and movement, weather, habitat and communications networks. Also, they associate consequent crisis (including eco-social and environmental difficulties) with dust storms effect (Mehdi et.al., 2014).

The increase in the frequency of sand and dust storms leads to an adverse effect on air quality (AQ) and also it affects negatively the climate and human health. WHO and EPA have set air quality standards to ensure human safety and developed a model (known as AirQ+) to assess that. This model has been used in numerous studies to evaluate the risk associated with particle exposure in various cities, including Athens, Cairo, and Makah (Abbas, 2021). The same software, accordingly, can be used here to study the effect of dust storms in Hilla city/ Iraq. Such study is crucial since there an urgent need to assess their impact on people human health in this Iraqi city (especially during the year 2022 where six dust storms have been recorded) . It is believed that the current work can be used as a guide to assess the detrimental effect of dust storms in general.

## Materials and Methods

### Study area

Hilla city occupies the northern part of the Babylon which is one of the central Iraqi provinces. Geographically, the city is between Najaf and Baghdad province. It is precisely located on 44.43 longitude and 32.48 latitudes coordinates with a desert climate characterized by low rainfall and high summer temperatures as high as 50 ◦C. The population of the city is 628,861 and 645,016 for the years 2021 and 2022, respectively. The region has many sand dunes, which contributes to the formation of dust storms, as well as the increase in area that have undergone desertification and the decline of agricultural lands, both of which are reflected on the environmental aspect. The soil is, therefore, considered one of the important natural parts because of its significant and obvious impact on weather manifestations, particularly on the phenomenon of the formation of dust storms.

### Data used

Three air quality monitoring stations in Hilla have been used to collect the daily mean concentration of PM2.5 and the monthly mean of meteorological data (temperature in degrees Celsius, humidity in percentage, wind direction in degrees, wind speed in meters per second, and rain in millilitres) for a period of time extending from January 2021 to January 2023 . The first station is located in Babylon University while the others are in the Hilla textile factory in the Nader neighbourhood, and in Abu Khastawi. All stations belong to Babylon Environment Directorate. For a fair measurement, the arithmetic average of the recorded data from the three stations was taken and used as input parameters in AirQ+ software.

Samples were collected using beta attenuation mass device (BMA 1020, Met-One Instruments Inc., Grants Pass, OR, USA) and it is shown in Fig.1. The device contains a tiny carbon-14 element that emits beta rays continuously through a filter tape. A vacuum pump loads ambient PM2.5 onto the filter tape by allowing a regulated amount of air to pass through it. The mass of PM2.5 on the filter tape is identified using the attenuation of the beta ray signal, and the volumetric concentration in the surrounding air is computed. To meet the US EPA Federal Equivalent Method designation for continuous PM2.5 monitoring, specific settings and accessories were used. These are 42 minutes of active sampling phase (from time xx:08 to time xx:50 per hour). This is followed by 18 minutes of tape movement and filter tape reading before and after the sampling period. This measuring preducture is reported in details in the work of McNamara et.al (2011).

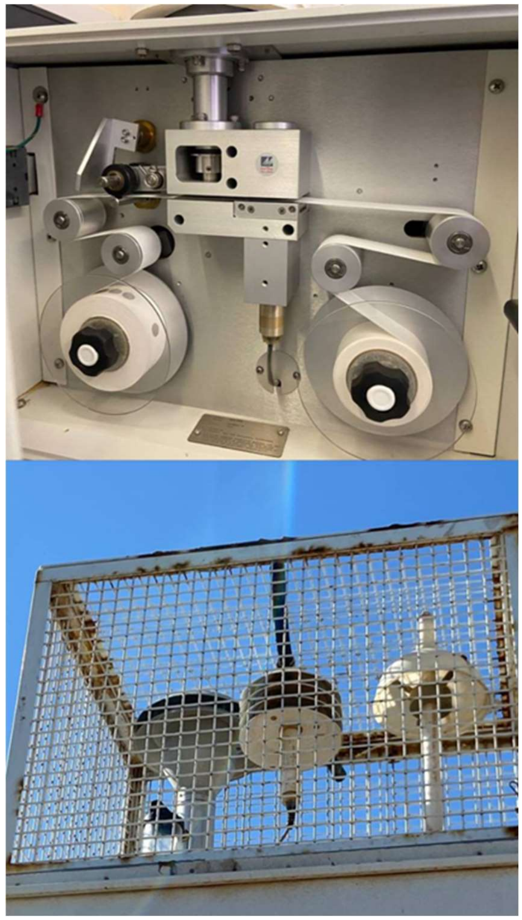

Fig 1. BMA 1020 device .

**3. AirQ+ Computations**

As mentioned, AirQ+ software is used in this study to assess the health impact of long- and short-term exposure to pollutants. The assessment in the current work is based on:

**3.1. Relative Risk (RR)**

This parameter is defined as the chance of an event to be happened in an exposed population group divided by the probability of an event that can happen in a non-exposed group. This parameter helps determining directly the relationship between exposure and illness. A log-linear formula is commonly used to model the relative risks parameter to a pollution in air and this relation is as follows:

$$\mathbf{RR} = \mathbf{exp}^{\boldsymbol{\beta}(\mathbf{X}-\mathbf{X_0})} \qquad (1)$$

where

Xo is the cut-off or counterfactual such as the background concentration or the lowest feasible value and X is the contaminant concentration (in µg/m3). ß represents the change in the RR that is equivalent to a one-unit change in the contaminant concentration (WHO, 2018).

### 3.2. Attributable Proportion (AP)

AP is the proportion of the population at a given level of exposure. In other words, it means the part of the infection rate that can be reduced if the source of exposure is eliminated and that is related to the quantification of health effects WHO, 2018).

The percentage of health that can be assigned to exposure in a given population for a specific period can be calculated using Eq.2 developed by Krzyzanowski (1997). The equation is basedd on assuming that there is a causal relationship between exposure and health result and that there are no substantial confounding factors:

$$\mathbf{AP} = \mathbf{SUM}\frac{\{[\mathbf{RR(C)} - \mathbf{1}] * \mathbf{P(C)}\}}{\mathbf{SUM}[\mathbf{RR(C)} * \mathbf{P(C)}]} \quad (\mathbf{2})$$

where

RR , as defined previously, is the relative risk of an exposed group (here is named group C), P(c) stands for the exposed group C population ratio.

### 3.3. Incidence of Exposure (IE)

The quantity attributable to population exposure can be determined using the baseline incidence of the chosen health results and will be computed as follows:

$$\boldsymbol{IE = I * AP} \quad (\mathbf{3})$$

where

I is the population-wide baseline incidence of the health result.

### 3.4 Quantity of Cases Attributed to Exposure (NE)

The last parameter can be computed is the quantity of cases attributed to exposure and that parameter can be estimated as a function of the number of population (N) as follows (Fattore, 2011):

$$\boldsymbol{NE = IE * N} \quad (\mathbf{4})$$

## Results and Discussion

### 1. PM2.5 concentrations

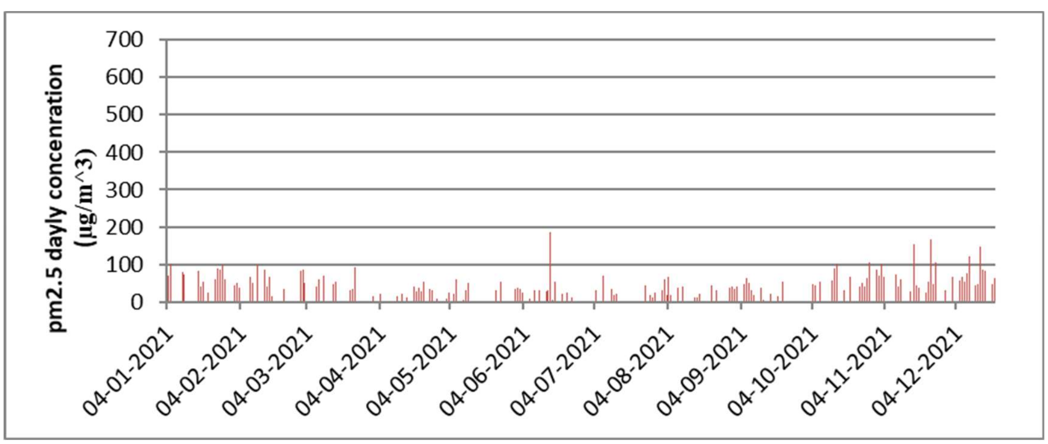


Fig 2. PM2.5 daily mean concentration for 2021.

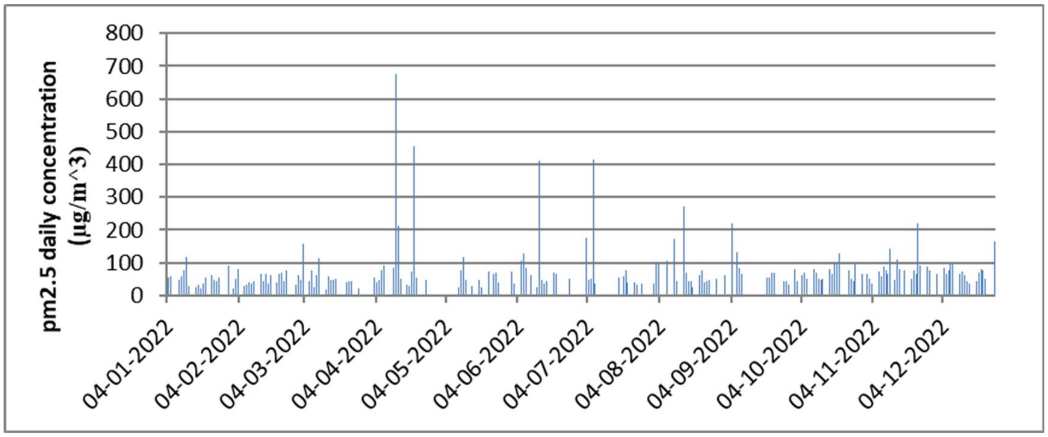


Fig 3. PM2.5 daily mean concentrations for 2022.

Figures 2 and 3 present the average values of PM2.5 daily concentration for Hilla city in 2021 and 2022, respectively. Looking closely at the results, it is clear that the concentrations has exceeded Iraqi air quality standards (i.e. 25 µg/m3, 24-hour mean, and 10 µg/m3 annual mean) in many days. Comparing the concentrations values in the these sequent years, one can find that the lowest concentration is 3.22 µg/m3 and the highest is 185 µg/m3 in 2021, while in 2022 the corresponding values are 16.8 and 674 µg/m3, respectively. It is important to note here that the highest value in 2022 represents a dust storm day. These results reveal that pm2.5 is consistently high, indicating to a series air pollution occurred in Hilla city during 2022. As discussed previously, this can have detrimental implications on the health of the citizens since high levels of PM2.5 can contribute to respiratory problems and even lung cancer for the long term exposure. Moreover, the environmental impact of air pollution is also significant and can lead to consequences such as acid rain and the eutrophication of water bodies. Therefore, it is crucial to undertake measures to control and reduce air pollution levels in the city.

Air Quality Index provides information on air quality and the amount of basic pollutants in it, so that the air quality index is calculated according to the concentrations of pm2.5 in the current study. To evaluate the air quality at pm2.5, the Indian specifications are taken as a reference because they are closer to the Iraqi standards and the standards of the WHO. Table 1 shows Air Quality Index for PM2.5 Parameter and there safe exposure limits.

**Table (1): Air Quality Index for PM2.5 Parameter and there safe exposure limits**

| AQI | Color | PM2.5(µg/m$^3$) |
|---|---|---|
| Good | Green | 0-30 |
| Moderate | Yellow | 31-60 |
| Unhealthy for sensitive groups | Orange | 61-90 |
| Unhealthy | Red | 91-120 |
| Very unhealthy | Violet | 121-250 |

| | | |
|---|---|---|
| Hazardous | Dark red or brown | +250 |

Figure 4 shows the highest percentage of air quality in 2021. It is clear from the figure that air quality index is moderate (see Table 1) until it reaches 19% where it is considered unhealthy for sensitive groups. Lower than that (i.e. 5%) is also unhealthy but it not hazardous because of the absence of dust storms during 2021 and the weather was clearer comparing to that in 2022. Figure 5 shows that 2% is hazardous and 6% is very unhealthy which are the days of dust storms where the concentrations ranged approximately from 200 to 700 µg/m3. The air quality for pm2.5 this year is considered to be moderate, with a rate of 45% to be unhealthy for the sensitive group. Further, the air quality in 2021 was better than that in 2022, as it was characterized by normal rates of rain and humidity, which contributed to the absence of the problem of dust storms and that appeared significantly in 2022.

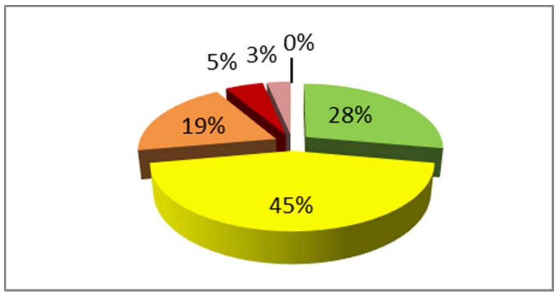


Fig 4. AQI Categories of pm2.5 in 2021.

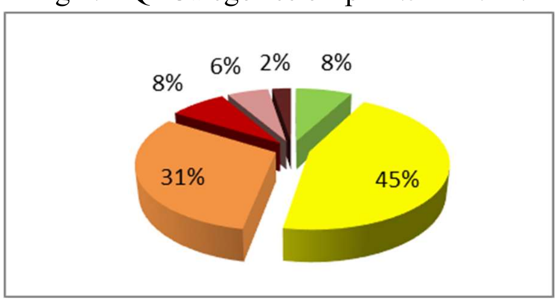


Fig 5. AQI Categories of pm2.5 in 2022.

## 2. Impact Assessment

**Short-term exposure to pm2.5**

Short-term exposure (acute exposure) is when one be in contact with the pollutant during short periods that lasts for hours. Exposure is the major driver of changes in disaster risk, and of impacts when risk is realized (Cardona et.al., 2012). It is important to remind here that short-term exposure to PM2.5 causes health effects, including admission to hospital due to respiratory diseases(RD) and admission to hospital due to cardiovascular diseases(CVD).

### 1. Cardiovascular disease (CVD)

CVD is a term encompassing conditions that harm the blood vessels and heart. It is frequently associated with atherosclerosis, an accumulation of fatty deposits in the arteries that increases the risk of blood clots. Atherosclerosis in several organs, including the eyes, heart, brain, and kidneys, may also be connected to it (Nabel, 2003).

All dust storms occurred in spring and summer months (which are considered dry months) usullay decrease in the wet months. In general, dust storms led to an increase in the concentrations of pm2.5 in the air. Using AirQ+, the health effects associated with exposure to the pollutant during storm days can be calculated. Figure (6) shows the relative risk of concentrations of dust storm days, where the highest risk recorded (RR) was 1.801(95% CI = 1.116 – 2.913) for the concentration of 674 µg/m3, with an attributable proportion of 44.48%. According to statistics, this led to an increase in the number of hospital admissions due to cardiovascular diseases by 702 (165-1037). The lower extent of RR is 1.477(95% CI =1.075 –2.033) for concentration of 456 µg/m3 with attributable proportion of 32%. This led to an increase in the number of hospital admissions due to cardiovascular diseases by 521 (114-819). For concentrations 414, 411, 271 and 214 µg/m3, the value of RR is 1.422(95% CI =1.068 – 1.897), RR= 1.419(95% CI =1.067 –1.889), RR= 1.249(95% CI =1.042 –1.498) and RR= 1.186 (95% CI =1.032 –1.364) respectively with attributable proportion 29.7%, 29.53%, 19.94% and 15.73% respectively. These values, as expected, led to an increase in the number of hospital admissions due to cardiovascular diseases by 421(91-671),419(90-667),193(40-322) and 142(29-241), respectively.

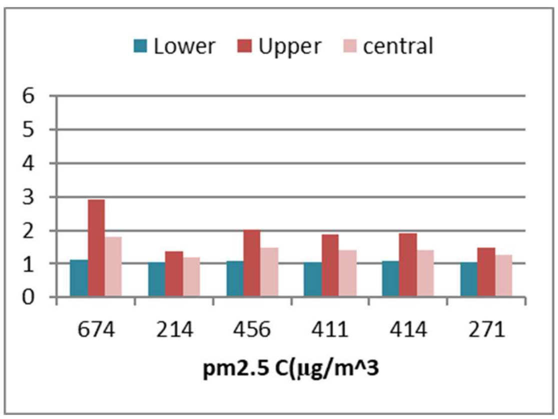


Fig 6. Relative risk (RR) of hospital admissions due to cardiovascular diseases(CVD).

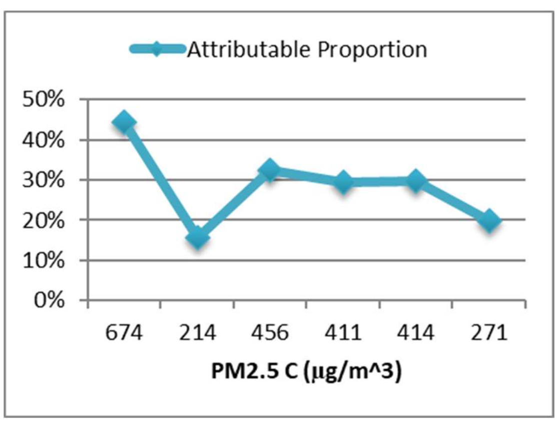


Fig7. Attributable Proportion (AP) of hospital admissions due to cardiovascular diseases.

**2. Respiratory diseases(RD)**

The lungs are a component of an intricate system that constantly expands and contracts to take in O2 and release CO2 throughout the day. Any dysfunctional part of this system can cause lung disease (Demedts et.al., 2001).

Observing the relative risk for short-term exposure, one can find that the relative risk of respiratory diseases is greater than cardiovascular diseases. This is because that the respiratory system is in direct contact with the air and its pollutants, so the effect on respiratory diseases is greater than the other. Figure (8) shows the relative risk of concentrations of dust storm days, where the highest risk recorded (RR) is 3.395 (95% CI= 1 – 12.993) for concentration 674 µg/m3, with an attributable proportion of 70.55%. Accordingly, an increase in the number of hospital admissions by 1592 (0-2083) is recorded due to respiratory diseases. When the concentration is within the standard of WHO, the relative risk is R = 1. If the relative risk is equal to one, the short-term exposure to the pollutant does not affect human health and the attributable proportion (AP) is equal to zero. It is inportant to stress here that the concentrations during the dust storms are higher than the standard specifications, causing severely harmful health effects. For a lower extent, RR is 2.25(95% CI =1 –5.466) for concentration 456 µg/m3 with an attributable proportion of 55.57%, leading to an increase in the number of hospital admissions due to respiratory diseases by 896(0-1318).

For concentrations 414, 41, 271 and 214 µg/m3, RR is 1.422(95% CI =1–4.633), 1.419 (95% CI =1– 4.584), 1.249 (95% CI =1–2.632) and 1.186 ( 95% CI =1–2.105), respectively with attributable proportion 51.92, 51.67, 37.01% and 29.92% respectively. Accordingly , again, an increase in the number of hospital admissions due to respiratory diseases by 737(0-1113), 733(0-1109), 359(0-601) and 270(0-474).

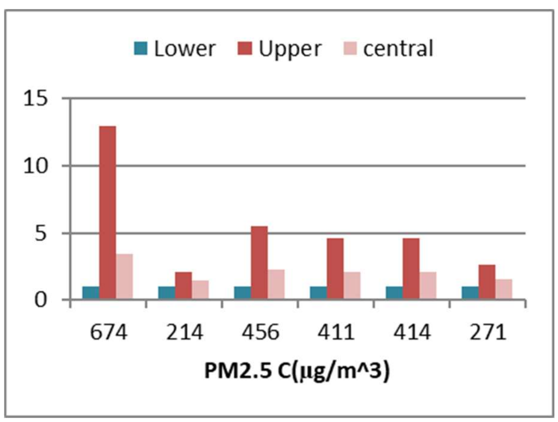


Fig 8. Relative risk (RR) of hospital admissions due to respiratory diseases(RD).

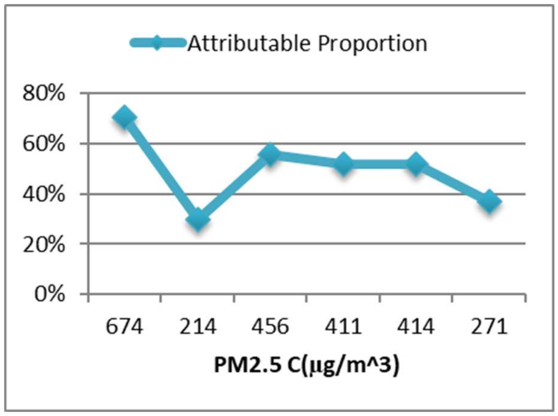


Fig 9.Attributable Proportion (AP) of hospital admissions due to respiratory diseases.

## 3.Application of Artificial Neural Network Modeling For Estimating the Types of Dust Storms

Models based on artificial neural networks are effective at predicting the kinds of dust storms that might expose people to high levels of pollution in the air for a short period of time(Alshammari, R.K., 2022). These models can take into account a variety of factors, such as wind speed, soil moisture content, and atmospheric stability, in order to anticipate dust storms' occurrence and characteristics. These models could be used by researchers to learn more about dust storm air pollution's causes and transport routes, as well as to come up with effective ways to reduce the health risks it poses to vulnerable populations (Marko Tainio, et al.,2021). A novel approach to assessing the kinds of dust storms and the potential health effects is to use an artificial neural network model. By analyzing numerous environmental factors and meteorological conditions, this model is able to accurately predict various storm types and their strengths. This considers early general wellbeing measures by giving a gauge of the volume and sort of particulate matter that will be released up high during such events. Because it makes it possible for authorities to take prompt measures to safeguard public health and lessen the negative effects of air pollution, this strategy may be especially useful in locations that are prone to dust storms. A typical Neurons are variously known as processing elements (PEs), or nodes, the input from each (PE) in the previous layer ( Xi) is multiplied by an adjustable connection weight (Wij) at each PE, the weighted input signals are summed, with a threshold value (θj ) may be added. This combined input (Ij) is then passed through a transfer (activation) function to produce the output of the PE (Yj), the output of one PE provides the input to the PEs in the next layer .

This process is summarized in equations (5) and (6), as cited by AL-Zwainy (2008).

$$Ij = \sum WijXi + \theta j \qquad (5)$$

$$Yj = f\,(Ij) \qquad (6)$$

Where:

$Ij$ is the activation level of node j; $Wij$ is the connection weight between nodes i and j; $Xi$ is the input from node I, i = 0,1,……,n; $\theta j$ is the bias or threshold for node j; $Y j$ is the output of node j; and f : the activation function.
The artificial neural network model for estimating the types of dust storms were developed using the soft wares of " SPSS version 2019",Where we divided dust storms into three classes (class1 moderate to light, class 2 moderate to severe, class3 light ) . The model used ( Air temp in ◦C ,humidity in %, wind direction [°] , wind speed in m/sec and rain in ml ) as input variables . This model architecture and normalized importance for input parameters, which indicate that the rain, recorded 100% importance among all parameters but less importance was 8 %, recorded at air temp, are shown in Figure (10) and figure (11), respectively. 30 running have done to predict that model, the training percent was 70%, testing 10% and validation 20%.

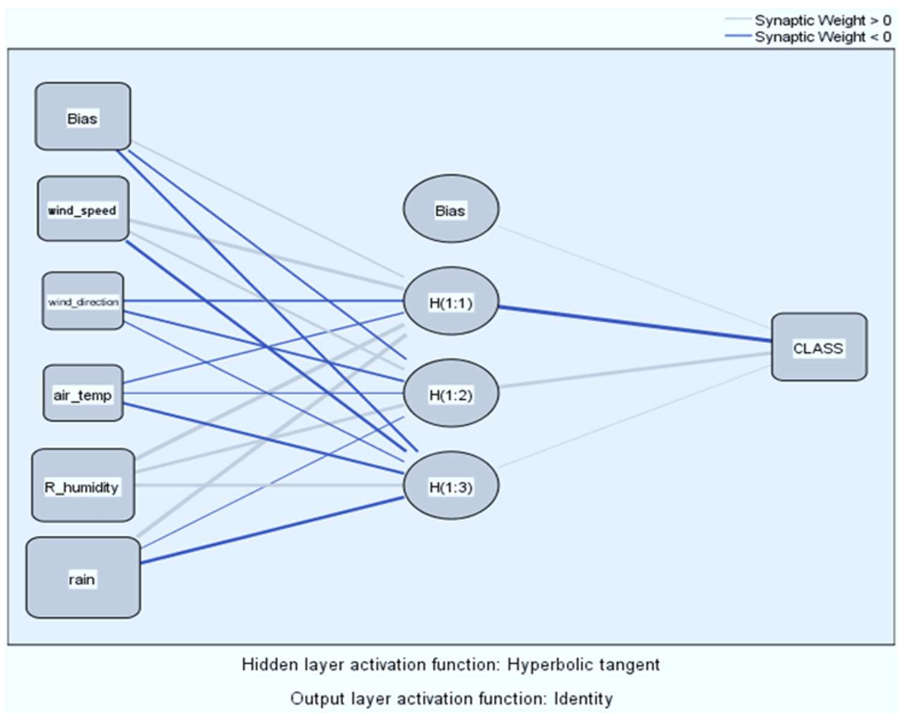


Fig 10.The ANN Model Architecture for classes of dust storms.

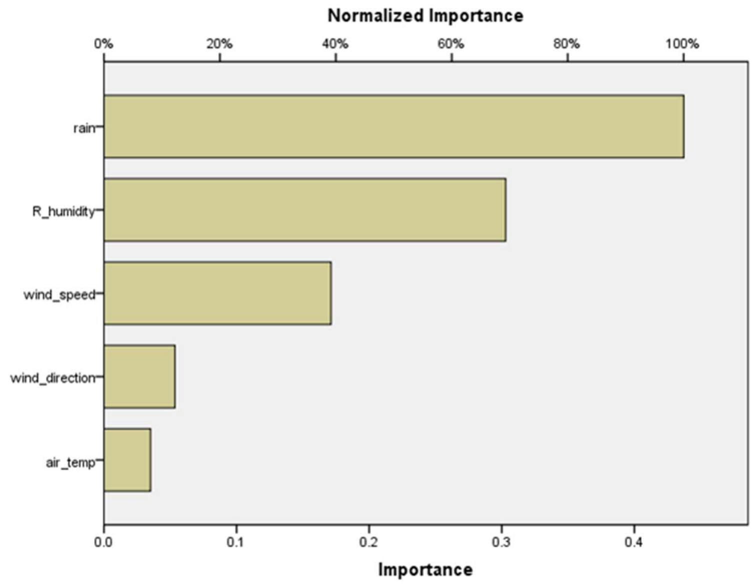


Fig 11. Normalize the Importance for Input Parameters.

**Conclusion**

The main goal of the current work is to assess how short-term exposure to PM2.5 pollution during dust storm days affects people's health in the city of Hilla. A list of conclusions can be drawn and these are as follows:

Exposure to air pollutants can cause acute short-term health effects and long-term chronic effects. pm2.5 is one of the most dangerous air pollutants that govern the air quality index.

Dust storms in 2022 made the air quality poor in the region. It made the air quality dangerous by 2% and very unhealthy by 6%.

The air quality was moderate at a rate of 45% to unhealthy for sensitive groups at a rate of 31% in 2022 and good at a rate of 28% to moderate at a rate of 45% in 2021.

To assess the health impact during dust storm days of short-term exposure to pm2.5 pollutants, AirQ+ software is used to extract the relative risk (RR), and attributable proportion (AP) to respiratory diseases and cardiovascular disease.

According to the Iraqi and the World Health Organization(WHO) standard for air pollution of PM2.5 (25 µg/m3, 24-hour mean, and 10 µg/m3 annual mean). When the concentration is within the standard, the relative risk (RR) equals one. If the relative risk is equal to one, the short-term exposure to the pollutant does not affect human health, and the attributable proportion equal to zero.

The most severe dust storms (674 µg/m3) caused an increase in the relative risk to 3.395 for respiratory diseases and 1.801 for cardiovascular disease, which is considered hazardous to human health, as it caused an increase in the number of admissions to hospital, 1,592 cases of respiratory diseases and 702 cases of cardiovascular disease.

For a lower extent, RR= 2.25(95% CI =1 –5.466) for concentration 456 µg/m3 with an attributable proportion of 55.57% which led to an increase in the number of hospital admissions due to respiratory diseases by 896(0-1318). Also, it has been noticed that RR=1.477(95% CI =1.075 –2.033) with attributable proportion 32. 32% which led to an increase in the number of hospital admissions due to cardiovascular diseases by 521 (114-819).

The lightest dust storms (214 µg/m3) caused an increase in the relative risk to 1.426 for respiratory diseases and 1.186 for cardiovascular disease, which are considered also hazardous to human health, as it caused an increase in the number of admissions to hospital, 270 cases of respiratory diseases and 142 cases of cardiovascular disease.

The relative risk and number of cases for respiratory diseases is greater than for cardiovascular diseases, because the respiratory system is in direct contact with the air, so the effect on it is greater.

The artificial neural network model used for estimating the types of dust storms this modeling determined that rain affects 100% of dust storms and their occurrence, and that temperature is the least influential among the parameters used.

Further study is needed, however, to evaluate and develop these models, as well as to account for the complex interplay between meteorological, environmental, and socioeconomic elements that might alter air quality during dust storms. Given the disturbing situation of the pollutant and its significant impact on health, the concerned authorities must take preventive measures to reduce or control the pollutant during periods of dust storms.

## REFERENCES

Abbas, T. R., & Abbas, R. R. (2021, February). Assessing the health impact of air pollutants in five Iraqi cities using the AirQ+ model. In IOP Conference Series: Materials Science and Engineering (Vol. 1094, No. 1, p. 012006). IOP Publishing.

Alshammari, R. K., Alrwais, O., & Aksoy, M. S. (2022). Machine Learning Applications to Dust Storms: A Meta-Analysis. Aerosol and Air Quality Research, 22, 220183.

Al-Zwainy, F. M. (2008). The Use of Artificial Neural Net Work for Estimate Total Cost of Highway Construction Projects (Doctoral dissertation, Ph. D. thesis, Civil Eng. Department, Baghdad University).

Bilal, M., Nichol, J. E., Nazeer, M., Shi, Y., Wang, L., Kumar, K. R., ... & Lolli, S. (2019). Characteristics of fine particulate matter (PM2. 5) over urban, suburban, and rural areas of Hong Kong. Atmosphere, 10(9), 496.

Cardona, O. D., Van Aalst, M. K., Birkmann, J., Fordham, M., Mc Gregor, G., Rosa, P., ... & Thomalla, F. (2012). Determinants of risk: exposure and vulnerability. In Managing the risks of extreme events and disasters to advance climate change adaptation: special report of the intergovernmental panel on climate change (pp. 65-108). Cambridge University Press.

Cuevas, E., Camino, C., Benedetti, A., Basart, S., Terradellas, E., Baldasano, J. M., ... & Schulz, M. (2015). The MACC-II 2007–2008 reanalysis: atmospheric dust evaluation and characterization over northern Africa and the Middle East. Atmospheric chemistry and physics, 15(8), 3991-4024.

Demedts, M., Wells, A. U., Anto, J. M., Costabel, U., Hubbard, R., Cullinan, P., ... & Taylor, A. N. (2001). Interstitial lung diseases: an epidemiological overview. European Respiratory Journal, 18(32 suppl), 2s-16s.

Fattore, E., Paiano, V., Borgini, A., Tittarelli, A., Bertoldi, M., Crosignani, P., & Fanelli, R. (2011). Human health risk about air quality in two municipalities in an industrialized area of Northern Italy. Environmental Research, 111(8), 1321-1327.

Goudie, A. S. (2014). Desert dust and human health disorders. Environment international, 63, 101-113.

Lodovici, M., & Bigagli, E. (2011). Oxidative stress and air pollution exposure. Journal of toxicology, 2011.

McNamara, M. L., Noonan, C. W., & Ward, T. J. (2011). Correction factor for continuous monitoring of wood smoke fine particulate matter. Aerosol and Air Quality Research, 11(3), 315.

Nabel, E. G. (2003). Cardiovascular disease. New England Journal of Medicine, 349(1), 60-72.

Najafi, M. S., Khoshakhllagh, F., Zamanzadeh, S. M., Shirazi, M. H., Samadi, M., & Hajikhani, S. (2014). Characteristics of TSP loads during the Middle East springtime dust storm (MESDS) in Western Iran. Arabian Journal of Geosciences, 7, 5367-5381.

Samadi, M., Darvishi Boloorani, A., Alavipanah, S. K., Mohamadi, H., & Najafi, M. S. (2014). Global dust Detection Index (GDDI); a new remotely sensed methodology for dust storm detection. Journal of environmental health science and engineering, 12, 1-14.

Tainio, M., Andersen, Z. J., Nieuwenhuijsen, M. J., Hu, L., De Nazelle, A., An, R., ... & de Sá, T. H. (2021). Air pollution, physical activity and health: A mapping review of the evidence. Environment international, 147, 105954.

Thalib, L., & Al-Taiar, A. (2012). Dust storms and the risk of asthma admissions to hospitals in Kuwait. Science of the total environment, 433, 347-351.

Tozer, P., & Leys, J. (2013). Dust storms–what do they really cost? The Rangeland Journal, 35(2), 131-142.

World Health Organization. (2006). Air quality guidelines: global update 2005: particulate matter, ozone, nitrogen dioxide, and sulfur dioxide. World Health Organization.

World Health Organization. (2018). AirQ+: A software tool for health risk assessment of air pollution.

Zhang, X., Zhao, L., Tong, D. Q., Wu, G., Dan, M., & Teng, B. (2016). A systematic review of global desert dust and associated human health effects. Atmosphere, 7(12), 158.