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RESEARCH ARTICLE

AMBIENT AIR QUALITY MONITORING DURING NAWRUZ FESTIVAL IN DUHOK CITY, IRAQ

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ABSTRACT

Nawruz is one of the most fabulous festivals celebrated in Kurdistan of Iraq (KOI) with joy and happiness. Nawruz is celebrated by people from diverse ethnic communities and religious backgrounds for thousands of years. During Nawruz festival, which held annually in KOI, thousands of firecrackers are set off, in an intense pyrotechnic spectacle. Firework displays are high-intensity anthropogenic activities that create notable air pollution and obvious short-term air-quality degradation. The study was conducted to determine the trends and variations of air pollution levels at Duhok city (DC), Iraq, as well as to create awareness about air pollution through availability of scientific monitoring data. The average concentration of SO2, and NO2 in DC area was slightly higher than the standard prescribed limit. While the average concentration of CO in DC area was almost lower than the WHO guidelines value. The concentration of particulate matters (PM) was ~ 5 times higher on festive day as compared to the non festive day at the study site of DC.

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INTRODUCTION

On different occasions, Fireworks (FW) displays are used worldwide as a part of festivals and national and cultural celebrations**.** People in different countries, burn crackers to express their happiness. Fireworks (FW) events have been concentrated within special periods during specific times of year, such as New Year's Eve (worldwide), the Diwali (or Deepawali) festival (DF) (Nov., India), Las Fallas (March, Spain), Lantern Festival (February, China), Guy Fawkes night in the UK (November, Nawruz (March, Iraq, Iran, Turkey, etc.), and other celebrations, such as Olympic Games. etc. Every year (in March), all over Kurdistan of Iraq (KOI), including Duhok city-DC, intensive fire ignition and cracker work activities takes place during the festival and celebration of Nawruz, (for a period of several days). These activities include burning huge amount of crackers, sparklers, wood and old used tyres, etc. These could be emit large amount of suspended particulate matter (PM), and toxic or poisonous gases such as oxides of sulphur (SO_x), oxides of nitrogen (NO_x), carbon monoxide (CO), etc. (Kong *et al.,* 2015). Therefore, FW in large amounts, aggravate the level of air pollutants and cause significant short-term air quality degradation, and are very harmful to health of all living beings, and severely affects the environment.

Atmospheric pollutants are responsible for both acute and chronic effects on human health (WHO, 2005). Firecrackers (FW) include a large number of chemicals such as potassium nitrates, sulfur, manganese, etc. (Ravindra *et al.,* 2003; Wang *et al.,* 2007; Crespo *et al.,* 2012), leading to extremely high ambient concentrations (cont.) of these species during using FW through celebrations. These heavy metals and perchlorates are all highly toxic (Shi *et al.,* 2011) and are on average fine enough to be easily inhaled and present a health risk to susceptible individuals. FW and crackers could be lead to serious injuries that are preventable, noise pollution (Yousif, 2015). Studies from countries around the world stress the importance of these global issues. (Singh *et al.*; 2005, Greene and Joholske, 2007). Other pollutants contribute to the air pollution (AP) include, atmospheric aerosols, which are particulate matters (PM), that are solid or liquid droplet larger than a molecule but small enough to remain suspended in the atmosphere. PM can originate from various natural sources (e.g. volcanic) and from various anthropogenic sources (e.g. automobiles, combustion industries, other natural pollutants, FW, etc.) (Vincent, 2007). In Iraq, we have other pollutants, such as dust pollutants emissions (e.g. dust storms), which contribute to AP. Generally, There are four common accepted PM fraction: (i) the ultrafine fraction is equal to or less than 0.1 µm in diameter (D), (ii) the fine fraction ranging from 0.1 to 2.5 µm, (iii) coarse fraction consist of PM equal to or more than 2.5 µm, and (iv) total suspended particulates (TSP) which is all PM equal to or less than 100 µm (Kelly and Fussel,

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2012). The evidence on airborne PM and its public health impact is consistent in showing adverse health effects at exposures in both developed and developing countries (WHO, 2006), e.g. air pollutants that are inhaled have serious impact on human health affecting the lungs, the respiratory and cardiovascular systems. Substantial evidence links respirable PM to human morbidity and mortality, especially in susceptible sub-populations (Samet *et al.,* 2000; Samoli *et al.,* 2008). Since, Health, Safety, and Environment program is paramount to the success of any operation or activity conducted by people in the society. It is morally justifiable to ensure that the health and well being of the communities are not threatened by any type of pollution related to anthropogenic activities. Therefore, highest level of safety awareness and environmental compliance is very important during any festival. There are set guidelines, from the World Health Organisation (WHO) for ambient exposure to PM10 and PM2.5. Table 1 presents the guideline concentrations (cont.), for both PM10 and PM2.5, for exposure over an annual or 24-hour averaging period.

Previous Studies

Several studies have been made all over the world based on the effect of Fireworks (FW) activities on the air pollution (AP), like particulate matters (PM) and its components, and trace gases during various festivals. A comprehensive review was conducted by Chow (1995), which included, regulatory compliance measurements, and discussions of size-selective inlets, flow measurement, etc. More recent review by McMurry (2000), focused on measurements of aerosol physical and chemical properties.

Table 1. WHO guidelines for exposure to ambient PM10 and PM2.5, adapted from (WHO, 2005)

	24 Hour (µg/m3)	1 Year (µg/m3)
PM10	50	20
PM2.5	25	10

The following are some related studies in some continents: In Europe, including Germany, researches regarding air pollution due to FW was carried out in several major cities (Drewnick *et al.,* 2005). In Italy, Vecchi *et al.* (2008) observed high loading of some heavy metals due to FW activities during the celebration of win of FIFA world Cup in the year of 2006 over Italy. In Spain, Moreno *et al.* (2007), investigated air pollution (AP) due to FW. In Hungary, Baranyai *et al.* (2015), studied the effect of a FW on the amount and elemental cont. of deposited dust collected in the city of Debrecen (Hungary). In America, a number of studies have been reported on the air quality (AQ) degradation for the firework activities during many festival in the USA. e.g. Lee *et al.,* 2006; Larson *et al.,* 2006; Hallar *et al.,* 2013) have noted elevated PM levels on Independence Day. Recently, a study is conduct by Seidel and Birnbaum, 2015) through observations of PM2.5 from 315 sites across the USA to estimate the effects of Independence Day FW on hourly and 24-hr-average concentration. In Asia several studies have been performed in the field of air pollution due to FW. e.g. In India, many studies were carried out to show the effect of FW during Diwali festival (DF). Ravindra *et al.* (2003) reported that FW lead to short term variation in air quality and observed 2 to 3 times increase in PM10 conct. in Hisar city (India). Kulshrestha *et al.* (2004) reported high level of different trace elements in ambient air of Hyderabad, which was due to FW during DF. Chatterjee *et al.,* 2013 reported the remarkable increase in PM10 cont. during DF in Kolkata. Other studies have also been reported on the air quality degradation for the FW activities during DF in other cities in India (Limaye & Salvi 2010, Mandal *et al.,* 2012; Pathak *et al.,* 2015, Verma & Deshmukh 2014). In China, Wang *et al.* (2007), studied the AP caused by the burning of FW during the lantern festival in Beijing. Xin, *et al.* (2012), investigated AP and Reductions of PM2.5 in Beijing-Tianjin-during the 2008 Olympic Games). In Korea, Zang *et al* (2015), investigated the effect of large-scale FW events on urban background trace metal cont. in Busan Metropolitan City (Korea). In Iraq, to the best of our knowledge, no published studies to date report about air pollution (AP) (due to fireworks- FW during Nawruz Festival-NZF) in Duhok City (DC), Iraq. And there is not any published research or scientific monitoring data about FW effects on air quality during NZF over Duhok City or over Kurdistan of Iraq (KOI). So this study is an original research, and can be consider the first-time study made at Duhok City (DC) or over KOI in this field.

Aims of the Study

The study was conducted to determine the trends and variations of air pollution (AP) levels at DC, as well as to create awareness about AP through availability of scientific monitoring data. The other objective of this study was to investigate the impact of fireworks (FW) on the short-term spatiotemporal variation of trace metals in PM during the NZF in Duhok city (DC). The characteristics of trace metals and elements making up the PM after firework burning were investigated. The author, also declare that there is no conflict of interests regarding the publication of this paper/ research.

MATERIALS AND METHODS

Site Description

Duhok City (DC), lies in the northwest of Iraq and western part of KOI (see Fig. 1), (latitude,36°5′N,longitude 43°0′). It is the 3rd most populous city of KOI situated about 430-450 m above mean sea level. More information about DC have been reported in earlier publication (Yousif; 2015). Air quality monitoring has been conducted near Duhok University. The experimental station and sampling location are depicted in Fig. 1.

Sampling Schedule and Data Sets

The monitoring work was done for a total number of 6 days spanned between March 18 to 24, 2014, to assess the variation in air quality due to FW during the Nawruz festival (NZF). A monitoring duration of 12 hours were maintained on each monitoring day. And two samples were collected daily at measuring site, from 11:00 am to 5:00 pm evening, and again from 6:00 pm to 12:00 am midnight (local time). Some Other measurements (such as Dust), a monitoring duration of 24 hours (for 7 days) were maintained on each monitoring day. Then cumulative samples were collected after one week.

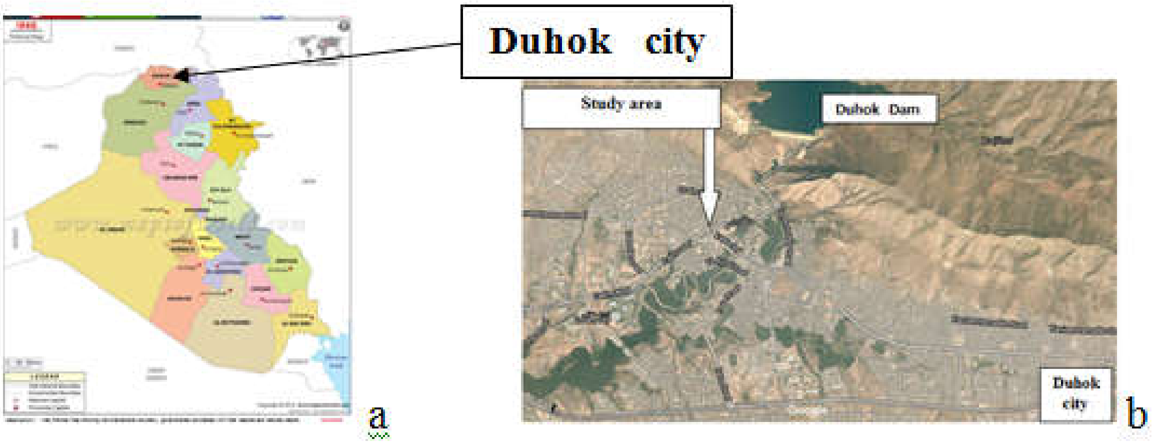

Fig. 1. Location of the monitoring site. a- Map of Iraq. b- Map of Duhok city. (adapted from Google, (www. Map sofworld.com/iraq/iraq-political-map)

The main festival (Nawruz Eve) (NZE) was on March 20th. Thus March 19 th, and March 21st (i.e. Nawruz Day) (NZD), were considered as Pre- Nawruz Eve (PNZ Eve) and Post-Nawruz Eve, respectively. And March 22nd, is considered as Post- Nawruz Day (PNZD), while March 18th and March 23rd were considered as normal days (ND1) & (ND2) respectively. The pollutant parameters measured during the study include different particulate species viz. PM10, and gaseous pollutants such as SO_2 , CO, and NO_2. The instruments were placed on 1.5 m high tables to avoid any obstruction.

Weather Parameters Measurement

The micro-meteorological parameters like temperature -T(°C), Relative humidity-RH (%), solar radiative flux(SRF) (W/m^2), atmospheric pressure, wind speed-WS (m/s) and wind direction have been measured during the study period. The anemometer and the wind vane assembly connected to the displayer, were kept on a 1.5 m high portable mast.

Gaseous and PM Measurement

The atmospheric trace gases which are the major gaseous pollutants, include sulfur dioxide (SO_2), nitrogen dioxide NO_2, and carbon monoxide (CO), were analyzed directly at the site location, using a portable gas analyzer (Drager-Multiwarn/ Germany). The instrument was calibrated against high purity standard gases, following the instruction given by Drager laboratories. Ambient suspended particulate matters (PM_{10}) were monitored by using a Thermo Scientific(Model The personal Data Ram -pDR-1200) with a stack monitoring equipment of pumping system of low flow rate (1 m^3/ min). Membrane filter (glass fiber circles -GFC), was used to capture particles for chemical analysis.

Determination of Heavy Metals

The chemical analysis of metals in PM10, were carried out using direct air-acetylene flame atomic absorption spectrophotometer (AAS) to determine the concentrations (conct.) of heavy metals (such as Cu, Fe, Pb, Zn, etc.) by using A Analyst 200, Perkin Elmer, USA Perkin Elmer spectrophotometer. The PM- loaded filters were extracted in an acid mixture to remove heavy metals. Each filter was placed in 30 ml conct. nitric acid (70%) and 10 ml hydrogen peroxide (30%) solution in a digestion vessel. The digestion vessels were placed on a sand bath and heated to 180°C for about 1 h until the acid solution had evaporated. The procedure was repeated twice and was continued until the residue was almost dry. Upon cooling, 60 ml water was added and agitated carefully. The solution was filtered into a 100-ml volumetric flask, diluted to the mark with de-ionized water, and used for the trace metal analysis with AAS. We used different standard reference materials for different metals for the calibration purpose.

Dust Measurement

Dust measurement of particulate AP within the selected site was measured by two procedures:

- Dust fall rate sampling was carried out in a plastic container (PC) which was previously washed with the distilled water (DSW). For this sample, the procedures described by Turk *et al.,* (1978) in Khopkar (2004), had been used. Briefly; a clean cylindrical PC (D = 38cm, height= 60 cm) was filled to one-fourth by deionized water (DW). Then the PC was leaved to expose for one week.
- Dust sample-2 were collected through a funnel (D=23cm) firmly attached with stopper to a conical flask of 1Lt. vol. has been placed on the roof of the building.

For both cases, systems were placed on the rooftop of the building on 1.5m high tables to avoid any obstruction. And a bird guard was kept around the sampling container so as to protect it from avifauna. After atmospheric exposure of container for one week, they were brought to the laboratory for further analysis. An oven dried and pre weighted glass fiber filter paper was placed over a filtration assembly through which all the liquid in the container was filtered into a graduated cylinder. The filter paper afterwards was oven dried at 105±2 °C for 2 hours. It was then cooled in a desiccator and re-weighted on an analytical balance and insoluble dust was computed.

Analysis of Dust by X-ray Diffraction

In this work, we have employed x-ray diffraction for the identification and analysis of the compounds present in dust samples. The XRD analysis was performed on powdered whole-sample specimens using a Philips automated diffractometer (PW 1820) with auto-divergence slits and monochromated Cu-Kα radiation. The sample rotates at a diffraction angle (θ), while the detector rotates at the angle (2θ). The *d* value (distance between atomic layers in a crystal) is calculated according to the Bragg law.

RESULTS AND DISCUSSION

Weather's parameters

The variation of temperature-T and relative humidity RH during the NZF are shown in Figs. 2 & 3 respectively. It was found that the T_{max} varied from 17±1.5 to 23±1.5°C . While the T_{min} varied from 8±1.5 to 9±1.5 °C. And the RH, varied from 58±2.5 % to 70±2.5 % during the day time and it, varied from 61±2.5 % to 81±2.5 % during the night times during the NZF. It was found that the mean SRF on normal days (228 ±3.5 to 235±3.5 W/m^2) was higher compared to other NZF days (203±3.5 to 223±3.5 W/m^2) (Fig. 4). Other average values of meteorological parameters recorded are presented in Table 2. It can be seen from Table 2, that the mean atmospheric pressure, and WS and WS on normal days were almost same as on festival days.

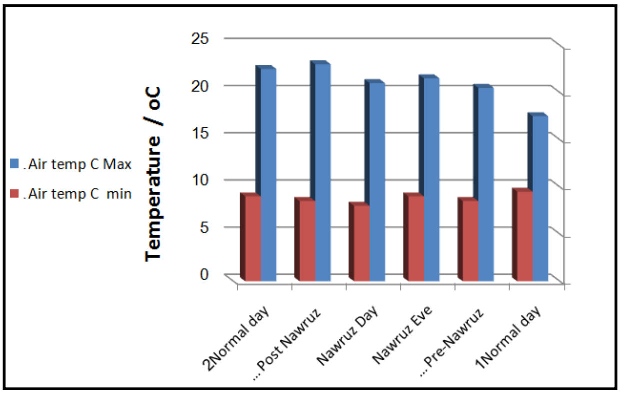

Fig. 2. Max and Min average of temperat-ure (°C) over DC, during the study periods

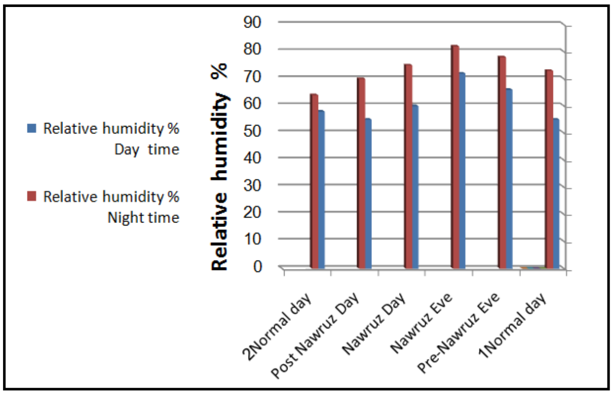

Fig. 3. Day and Night time average of RH, over DC, during the study periods

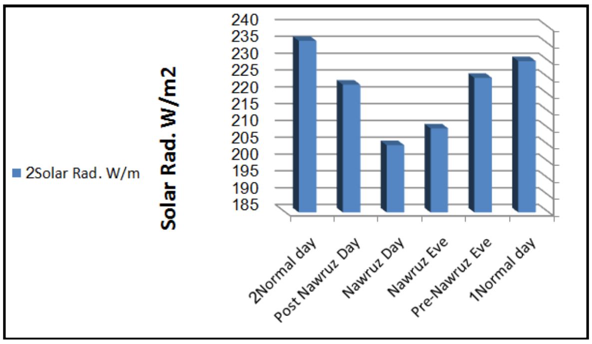

Fig. 4. Average of Solar Radiation over DC, during the study period

The mean WS was found to be slightly higher during the night-time compared to that during the day-time. Because low WS inhibits the dilution effect, meteorological conditions observed during NZF were favorable for the formation of secondary PM. During the most monitoring period the weather was a little hazy or misty (at evening). The sky remained more or less clear with a few scattered clouds sometime.

Table 2. Meteorological parameters recorded during the monitoring period

Day	Date of Monitoring	Wind Run		Pressure
		Avr.Speed m/s	direction	mbar.
Normal day1	18/3	1.0 ±0.2	SE	1015± 2
Pre-Nawruz Eve	19/3	0.9±0.2	SE	1015±1
Nawruz Eve	20/3	0.7±0.3	E	1016±1
Nawruz Day	21/3	0.7±0.3	NNW	1014±2
Post Nawruz Day	22/3	1.1±0.2	E	1014±2
Normal day2	23/3	0.9±0.2	WNW	1015±2

Table 3. The results of the air monitoring at selected location in the DC

Day	Date of Monitoring	Day -time/ Night-time	Monitoring hours	Concentration (µg/m^3)		
				SO2 (±5)	NO2 (±7)	CO (±2)
Normal day1	18/3	D	6	35.5	44.2	5.2
		N	6	50.6	54.5	6.8
Pre-Nawruz Eve	19/3	D	6	52.4	53.4	5.9
		N	6	64.8	91.6	11.1
Nawruz Eve	20/3	D	6	72.6	98.0	12.6
		N	6	82.5	105.2	28.8
Nawruz Day	21/3	D	6	81.3	98.3	21.2
		N	6	80.4	101.4	10.1
Post Nawruz Day	22/3	D	6	62.7	82.7	6.8
		N	6	51.5	72.5	5.9
Normal day2	23/3	D	6	60.5	62.5	8.4
		N	6	66.5	64.2	6.9
Limits/ Norms				80[a]	100[b]	(10 mg/m3)[c]

[a] *USA-EPA , National Ambient Air Quality Standards-NAAQ Standards, Annual arithmetic mean*

[b] *USA-EPA , NAAQ Standards, Annual arithmetic mean*

[c] *USA-EPA , NAAQ Standards, for 8-hour.*

Air monitoring

The results of the ambient air at selected location in the DC are summarized in Table 3. Gaseous pollutants including SO_2, NO_2, and CO, were analyzed. The results were evaluated in comparison with the guidelines prescribed by the World Bank Ambient Air Quality Norms (WBAAQN). The maximum cont. of SO_2, NO_2, and CO, was 82.5 ±5, 105.2 ±7, and 28.8±2 (µg/m^3), respectively, on night-time of NRZ Eve.

Generally, the results show (Table 3) that all air quality parameters, (gaseous pollutants SO_2, NO_2 and CO) were within the limits prescribed by the WBAAQN, with few exceptions (e.g. On Nawruz Eve, and Nawruz Day), where some parameters, such as SO_2, and NO2 appeared to be slightly increasing from the recommended levels. Since AP knows no boundaries, local activities such as FW displays can not only lead to local problems. It can lead to national and international consequences problems. There was a strong effect of night-time firework activities on the next day. The unfavorable meteorological conditions (lower WS, lower boundary layer height) for the dispersion of pollutants during night-time helps them to be accumulated near the earth surface till next day. Although we have not studied ozone, O_3, it is believed that the cont. of O_3 will increase by firecracker burning. High O_3 production by FW burning during DF has been reported by Attri *et al*. (2001) in India. Also Caballero *et al.* (2015) measured O_3, during FW Displays in Spain.

PM10 Aerosol during Normal and Festival Days

PM are complex mixture of elemental and organic carbon, mineral dust, trace elements, etc. We believe and expected that the detonation of FW to be a strong source of suspended particles. Large amounts of soot and metal oxide particles are emitted into the air. The 6 hrs average day-time (11 am–5 pm) cont. of PM10, and the 6 hrs average night-time (6 pm–12 am) cont. of PM10 aerosols during NZF days in DC have been shown in Fig. 5.

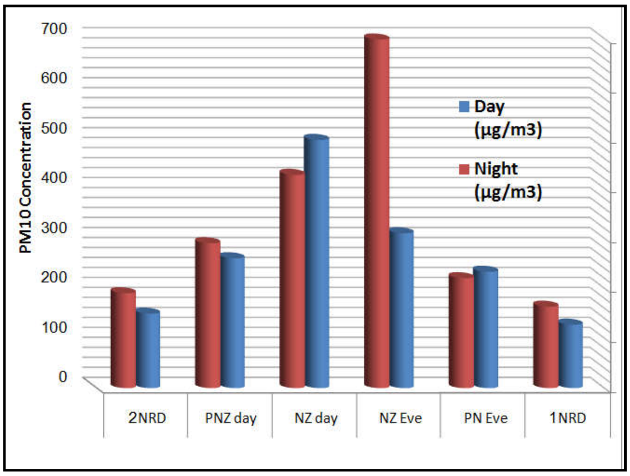

Fig. 5. Variation of PM10 concentration (Day and Night time average) over DC. during the study period

Where, NRD1 and NRD2, are Normal days. PN is Pre-Nawruz Eve, NZ is Nawruz Eve, NZ day is Nawruz day, and PNZ day is post Nawruz day. The results show higher PM10 aerosol cont. levels during NRZ was higher than during Normal Days (NRD). Also The results show higher PM10 cont. at night–time (6–12pm) was higher than the day–time (11 am –5pm) cont. at the location site. Also, on NRD, the night-time PM10 cont. (163 µg/m3) was found to be higher than day-time (127µg/m3). The cont. of PM was ~ 5times higher on festive day as compared to the non festive day at the study site of DC. This indicate that the mixing height decreases with the decrease in temperature, which allows the aerosol particles to be accumulated near the ground. Also the lower WS does not allow the particles to be dispersed which in turn enhances the surface cont. of aerosol particles. But, the higher thermal convection due to SRF, during day-time, increases the mixing height (Chatterjee *et al.,* 2013) which allows the PM to be dispersed, hence lowers the surface aerosol cont. during day-time. It is to be noted here that maximum FW activities occurred on NZ Eve. Therefore, the maximum cont. of PM10 aerosol (698 $\mu g/m^3$) was found on night-time of Nawruz Eve-NZ Eve, followed by Nawruz day- NZ day (497 µg/m3).

Chemical Analysis of PM

The PM was analyzed for the concentration of metals and it was deducted for the samples by AAS. For the determination of the heavy metal cont., calibration curves for each metal were prepared with 5 standard solutions at different cont. Metal solutions were aspirated into the flame of the AAS, where ions are reduced to the atomic state, and absorbed light can be measured quantitatively at a particular wavelength. However, the cont. of each metal were determined from the standard calibration curve of the individual metal. Ambient cont. of different heavy metals in PM10 samples collected during some of the monitoring period (NRD, and post- NZ Eve) are presented in Fig. 6.

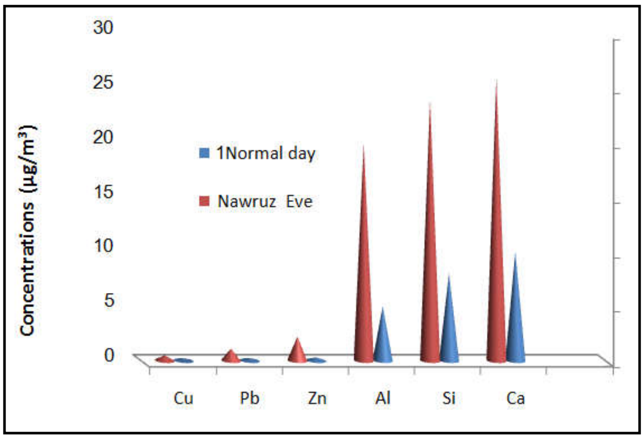

Fig. 6. Concentrations of the metals in PM10 samples during normal, and Nz Eve day

In this study Ca, Si, Al, Zn, Pb and Cu were found to be the most abundant elements in the atmosphere. There are several sources emitting trace metals in to the atmosphere during NZF over DC, such as the burning of crackers, sparkles, tyres, wood, and fields, etc. Most of the heavy metals are used to give colouring effects and flash, and to make the crackers more bright and colourful e.g. Fe, Cu, Co are used as colouring agents and to produce sparks. The oxides, or nitrates of some elements like Pb, Mn, etc. are used as the ready source of oxygen for the process of combustion of the firecrackers (Chatterjee *et al.*, 2013). Croteau *et al.* 2010 reported the emission factors of trace of various metals and elements for various types of FW, including Dragon Eggs, Ribbon Fuses, Roman Candles, Fountains, etc. Moreover, there are other sources of trace metals in to the atmosphere over DC, e.g. even on normal days indicating their source related to automotive/ vehicular emissions, soil and road dust, not paved roads, tyres wear, and diesel combustion to produce to electricity during using public generators. It is expected that the heavy metals cont. were varies considerably with the polluted, industrial & contaminated areas, depending on the wind speed and directions. Cont. of metals like Ca, Si, Al, Zn, Pb, and Cu, in collected PM10 were found to be increased by many times on Nz Eve (1.6, 2.0, 3.0, 6.33, 4.5 and 4.0 times, respectively) compared to the NRD. Thakur *et al.* 2010, reported that concentrations of metals like, Pb, and Cu in collected PM10 were found to be increased by many times during DF in Howrah, India (13.85, and 78.00 times, respectively) compared to the previous day.

The Dust fall Rate

We expected the detonation of firecrackers and fireworks to be a strong source of suspended particles. Large amounts of soot and metal oxide particles are emitted into the air during the detonation of fireworks, or burning huge amount of wood and old used tyres, etc. It is noticed that small airborne dust quantity is deposited (~ 0.225) gram /square cm. per week.

Analysis of Dust by X-ray Diffraction

Samples of the collect dust have been examined for mineralogical constituent. XRD data of the minerals phases were identified and found to closely match with data given in the International Centre for Diffraction Data (ICDD) (ICDD. 2012), the Powder Diffraction File (PDF). The following crystalline minerals and chemicals or compounds have been recognized:

- Quartz (silica) (SiO_2), which may derived from the surface friable and sheets and sand dunes which cover large area in west Iraq, as well as PM which are closely associated with FW.
- Calcite ($CaCO_3$), Bassanite ($CaSO_4$. $0.5H_2O$), and dolomite [Ca, Mg $(CO_3)_2$], originated from PM, as well as from carbonate rocks and calcite soil in the western desert of Iraq and from eastern borders of Syria.
- Feldspars ($KAlSi_3O_8$), exist in low percentages and may reflected to PM which are closely associated with FW, or due to the dry weathering of older sediments in the area.
- Lead sulfate ($PbSO_4$). exist in low percentages and may reflected to PM which are closely associated with FW or burning old used tyers, or leaded fuel.

The abundances of the major minerals varied depending on season and direction of wind. It probably relates to prevailing winds in different seasons having different strengths, such as the Shamal winds blowing over Iraq. The Results of XRD are in good agreement with other reported results (see McDonald and Caldwell, 2004).

Conclusions

Atmospheric pollution in Duhok city (DC), Iraq, was characterized in terms of trace gases, heavy metals, PM and dust. The main conclusions can be summarized as follows:

- The concentrations of most all of the elements of interest were higher in the post-fireworks display period than they were in the pre-fireworks period.
- Results of the air monitoring at selected location in the DC. (Table 3) conclude that concentration (cont.) of SO_2, NO_2, and CO, were within the limits prescribed by the WBAAQN. However, some parameters, such as SO2, and NO2), appeared to be slightly increasing from the recommended levels during the studied period.
- Firework (FW) activities had a strong effect in increasing the concentration of PM10 in DC. The cont. of particulate matters (PM) was about 5 times higher on festive day as compared to the non festive day at the study site of DC.
- In this study Ca, Si , Al, Zn, Pb and Cu were found to be the most abundant elements in the PM.
- The results of XRD, showed that at DC, the dominant minerals in the collected PM and the collect dust samples are quartz, Calcite, Bassanite Feldspars and Lead sulfate.

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