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TPH and heavy metal contents of dust fallout: a case study in educational and industrial areas in Kuwait

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Abstract Dust fallout in educational and light industrial areas in Kuwait was collected on monthly basis during the period from January to December 2014 at five sites. In addition, 20 dust fallout sediment samples were analyzed for TPH (total petroleum hydrocarbon) and heavy metals related to traffic and industrial activities such as As, copper (Cu), Mn, lead (Pb), and zinc (Zn). The results of this study reveal that: (1) monthly average dust deposition rates varied from 5.1 in educational areas to 50.6 g/m2 in industrial areas, with average deposition rate of 16 g/m^2; (2) the average concentrations for Zn, As, and Pb in the dust samples were up to 8.6, 7.3, and 6.5 times, respectively, higher than soil background values in Kuwait; (3) As, Cu, Pb, and Zn show significant enrichment relative to the upper continental crustal component (Mn); (4) contamination factor analysis for Pb, Zn, and As shows very high contamination level; and (5) TPH was the dominant pollutant in the dust samples. The distribution of the heavy metals in dust fallout and variation in its monthly deposition rates from site to site seem to be attributed mainly to the volume of traffic activities.

Keywords Dust fallout · Heavy metals · TPH · Contamination

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Introduction

Dust with different particle sizes is transported during sandstorms due to large area of drought and absence of vegetation cover on the Arabian Peninsula (Al-Dousari and Al-Awadhi 2012). The sources of the dust naturally exist from soil mineral erosion processes or an anthropogenic input due to human activities such as traffic and industrial sources (Adachi and Tainosho 2005). Dust can carry fine divergent types of contaminants and soil minerals with 0.2 m/s wind speed (Al-Dousari and Pye 2005) and deposits in topsoil by sedimentation, impaction, and interception processes (Li et al. 2001).

Contaminant exposure such as dust can be ingested, inhaled, or dermal absorbed and lead to serious health problems (Wei et al. 2010) especially the accumulation of potential toxic non-biodegradable metals such as Pb, Cr, Zn, and Cd in the urban environment. Road dust is commonly the main source of airborne settled dust in urban areas which includes vehicle exhaust particles, tire wear particles, and brake lining particles (Ahmed and Ishiga 2006).

Furthermore, the use of historical leaded gasoline contributes in the accumulation of lead in dust sampled in urban cities such as Palermo, Italy (Varrica et al. 2003). Kayseri, Turkey (Tokalioglu and Kartal 2006), and Cairo, Egypt (Abdel-Latif and SalehI 2012). Other metals such as Cu, Zn, and Cd can be recognized from tire abrasion and industrial emissions (Thornton 1991; Markus and McBratney 1996; Wilcke et al. 1998).

Except for the study carried out by Al-Awadhi and AlShuaibi (2013) in Kuwait City; unfortunately, no attention has been given to heavy metal contamination of dust fallout in other cities in Kuwait. Thus, this work evaluates the total petroleum hydrocarbon (TPH) and heavy metal contents such as lead (Pb), cadmium (Cd), zinc (Zn), copper (Cu), chromium (Cr), and nickel (Ni) in dust fallout in educational and light

industrial areas near Kuwait City, using enrichment and contamination factors analyses.

Area of study

The eastern part of the study area contains harbor (Mina Shuwaikh port), free trade zone, the headquarters of some Kuwaiti corporations, and many small industrial workshops, while the western part contains educational institutes and Kuwait University (Fig. 1). Dust storms, in the study area and Kuwait in general, are common during summer and may occur anytime during the year (Al-Dousari and Al-Awadhi 2012). It has been suggested that dust storms, rising dust, and suspended dust occur during 17.3, 46, and 35.9 % of the total dusty days, respectively (Al-Basri 1993). Safar (1980) stated that the annual average number of dusty days in Kuwait is 255.4 days, and the dust is continuously present 13 % of the day and night time, but this percentage increases to 25 % during daytime throughout April to August.

Materials and methods

The rate of airborne settled dust, for the period from January to December 2014, was measured using dust traps, modified design by Al-Awadhi (2005), at five sites (Fig. 1). The dust trap, manufactured locally, consists of a single-piece PVC bucket of 0.015-m diameter. A circular piece of 0.005-m stainless-steel mesh is fitted into the bucket so that it rests 0.08 m below the rim, and glass marbles fill the upper part of the bucket above the mesh to prevent collected dust from being blown away. All dust traps were fitted with a metal strap looped in an inverted basket shape over the top to discourage birds from roosting. The traps were installed at height of 3- and 10-m radius away from any building or street. The average daily dust fallout rate was calculated using the ratio between sample weight at specific sampling period and the area of the dust trap opening.

Inductively coupled plasma optical emission spectrometry (ICP OES) was used for seasonal metal identification in 20 dust fallout samples. Samples were digested by adding acid mixture of 2 ml HNO_3, 6 ml HCl, and 1 ml HF. The mixture was then left overnight, and a hot plate was used to heat the sample up to 100 °C. Then, the residue was dissolved in 15 ml of DI water. After that, the solution was filtered and diluted into a 25-ml volumetric flask. For the quality assurance purposes, aliquots of two certified reference materials (CRMs; SRM-NIST 2709 San Joaquin soil and SRM-NIST 2711 Montana soil) were measured using the same procedures.

Assessment of the dust fallout contamination was performed using enrichment factor (EF) and contamination factor (CF). The EF method described by Sutherland (2000) was used to evaluate the potential impact of the dust fallouts. The

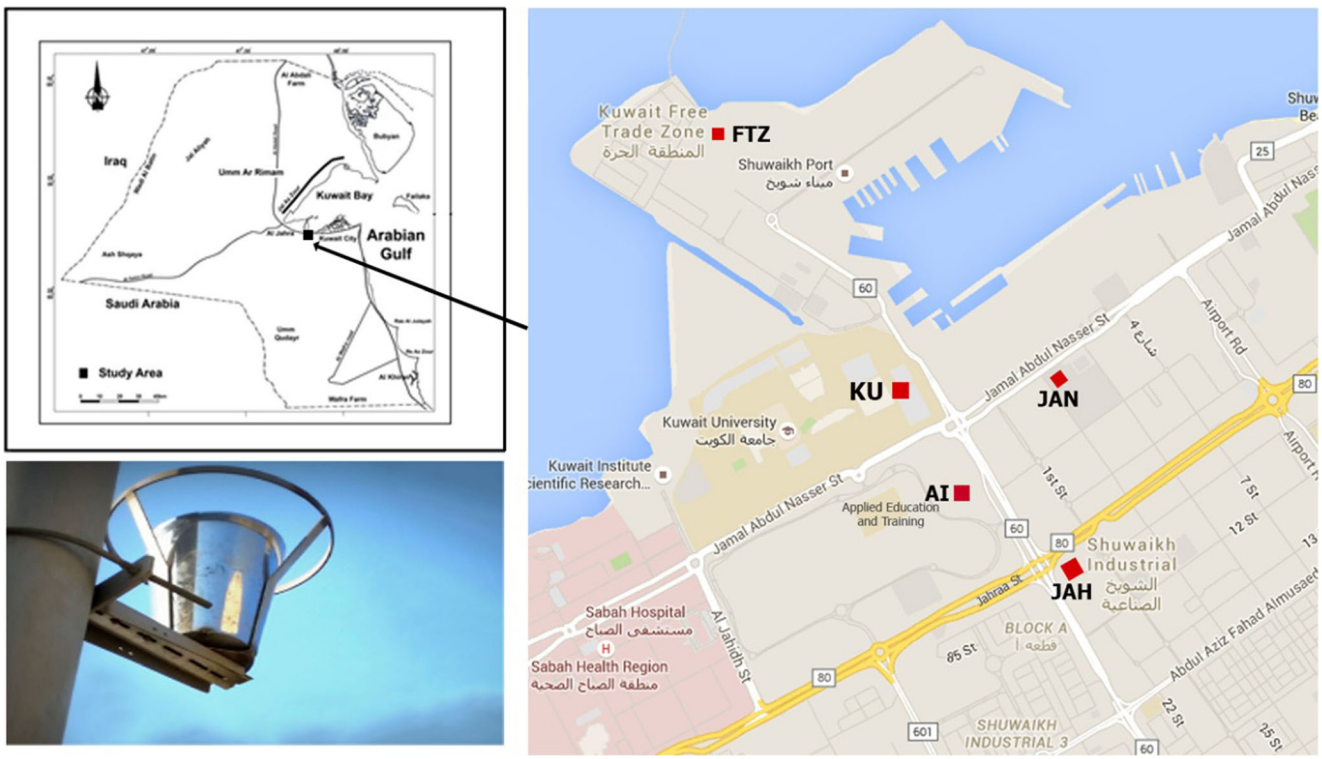

Fig. 1 Dust trap used in this study and location of the study area including dust sampling sites (sites AI and KU presenting educational areas while FTZ, JAN, and JAH presenting light industrial areas)

EF of element, which is normalization of a tested element against a reference one, was calculated using the following equation:

$$EF = \frac{\left[\frac{Cn}{Cref}\right] sample}{\left[\frac{Bn}{Bref}\right] Background} \quad (1)$$

where C_n (sample) is the content of the examined element in the dust fallout sediment, C_{ref} (sample) is the content of the reference element in the dust fallout sediment sample, B_n (baseline) is the baseline content of the examined element in Kuwait sediments, and B_{ref} (baseline) is the baseline content of the reference element in Kuwait sediments.

To assess the extent of contamination of heavy metals in dust fallout sediment samples, contamination factor used by Rastmanesh et al. (2010) was applied. The contamination factor (CF^i_f), for each single element index, is determined by the following equation:

$$CF^i_f = \frac{C^i_{0-1}}{C^i_n} \quad (2)$$

where C^i_{0-1} is the concentration of the element in the dust fallout sediment sample; and C^i_n is the background concentration of the element in Kuwait sediments.

Total petroleum hydrocarbons (TPHs) in the dust fallout samples were measured using the US-EPA 8015C method (GC analysis) and US-EPA 3540C (Extraction) procedure. The filter samples containing dust fallout sediments were extracted on Soxhlet Extraction unit (7890A GC system with flame Ionization Detector—Agilent) for 4 h with 60 ml dichloromethane, filtered with hexane, concentrated to 1 ml, and analyzed on GC system equipped with fused silica capillary column, operated in split mode using carrier gas, helium. Then, the samples were heated at 50 °C and gradually increased through three ramps up to 330 °C. The GC system was calibrated using C8-C40 standards from 175 to 1750 μg/ml, and the samples were quantitated against the curve generated through calibration.

Results and discussion

Deposition rate of dust fallout

The daily average depositional rates of dust for the five sites show that FTZ site which is located in the free zone area has the highest dust deposition rate throughout the year with average daily rate of 1.67 g/m^2, while the lower dust deposition rate was measured at JAN site with average daily rate of 0.17 g/m^2. The higher deposition rate at the FTZ site, with elevated rates during the summer season, is associated with the heavy traffic of trucks moving in and out the adjacent Shuwaikh port and ongoing construction works that transfer considerable amount of dust particles into the atmosphere to a deposition area. The number of vehicles running on the road in this site was obtained by personnel communication with the team leader of the ongoing road project; he indicated that the average daily number of vehicles running in to the area ranges from 71,885 to 128,920 vehicles per day. The elevated dust deposition rate in the summer season can be associated with the fact that dust storms in Kuwait can occur any time of the year but occur mostly during summer, and less frequently during other seasons. The low average deposition rates at the other sites might be due to the surrounding trees, which block some of the dust transported in the atmosphere, or less impact of traffic volume (Fig. 2).

The monthly average deposition rates at the sites varied from 5.1 (JAN) to 50.6 g/m^2 (FTZ) with average deposition

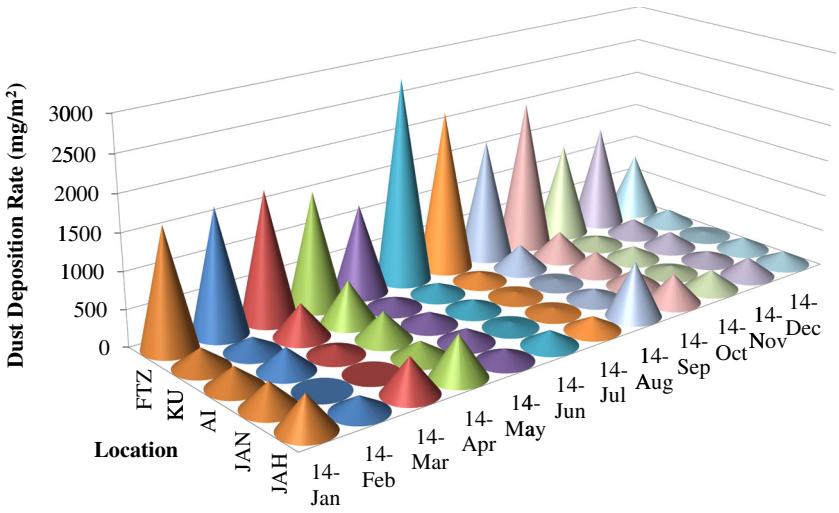

Fig. 2 Daily dust depositional rates with respect to month and location

rate of 16 g/m^2. Higher deposition rates in summer (June to August) were observed at all sites; the highest monthly deposition rate is observed in March (21.8 g/m^2). This observation is different from general trend of dust storm days counted in March, every year using airport meteorological data, where the dust storm days peaked in June and July (Al-Dousari and Al-Awadhi 2012).

The annual average rate of dust deposition for the study area reached 197.4 g/m^2/year, with minimum and maximum deposition rates of 50.7 (JAN) and 601.1 g/m^2/year (FTZ), respectively. Although this average value is more than the average dust deposition rate in the open desert areas in Kuwait (61.3 g/m^2/year; Al-Dousari and Al-Awadhi 2012), it is less than the dust deposition rate observed in Kuwait city, 590 g/m^2/year (Al-Awadhi and AlShuaibi 2013). These findings may again confirm the role of city traffic in emitting airborne dust into the atmosphere.

Metal contents of dust samples

The metal concentrations in the dust fallout in the study area show that Ca and Mg concentrations were the highest in the sample collected from all sites with average concentration values of 23,757 and 12,642 mg/kg, respectively (Table 1). The concentrations of the metals ranged from 0.1 (Co) to 32, 692 mg/kg (Mg). The mean seasonal concentrations of the elements in the dust fallout show that the toxic metal-related pollutants, direct or indirect, to traffic emission decrease in the order of Zn (342.1), Mn (204.6), Ni (79.8), Cu (56.5), Cr (40.9), and Pb (34 mg/kg); i.e., the Pb concentrations were the lowest among these measured toxic elements in the sample collected from the sites.

Furthermore, correlations between elements based on the whole data showed that Ni is strongly correlated (r>0.7) with Fe, As, Mn, Mg, and V, while Pb is more strongly correlated (r>9) with Fe, As, Mn, Mg, and V (Table 2). However, the Cu

Table 1 Seasonal and site concentrations of elements in dust fallout samples

Month	Site	Pb	Ni	Ca	Zn	Sb	Mg	Fe	Cr	Mn	Co	As	Cu	V
Jan-14	FTZ	49.0	145.7	39573.5	520.8	–	27927.0	13949.8	67.6	307.7	12.5	–	78.1	41.9
	JAN	47.8	96.0	15131.6	1465.2	28.2	17762.0	14148.8	68.7	271.6	12.6	–	86.9	43.5
	JAH	88.2	199.5	34180.3	825.1	–	32692.0	24213.9	117.5	424.4	19.0	–	164.2	71.1
	AI	23.5	46.3	7497.1	267.2	33.8	8141.0	7413.7	58.5	132.7	8.0	–	44.6	25.4
	KU	74.2	56.8	9356.8	757.1	–	10616.0	9791.5	58.1	184.6	6.9	–	52.2	37.9
Apr-14	FTZ	40.9	100.3	43804.9	401.9	–	20815.0	13104.1	51.3	325.8	13.1	–	58.2	35.2
	JAN	21.4	17.2	21531.3	340.6	5.8	9753.0	10561.2	30.2	204.8	8.1	37.2	97.4	23.6
	JAH	52.6	70.9	69989.1	380.1	–	24114.0	20997.7	80.2	537.8	16.3	78.7	59.7	54.9
	AI	16.7	36.4	35882.5	222.0	31.5	16880.9	18234.2	51.4	396.7	14.4	–	70.8	44.2
	KU	26.6	55.8	53205.5	396.8	–	18993.0	20103.7	68.5	425.6	16.8	48.1	52.6	43.0
Jun-14	FTZ	18.7	105.7	39807.0	241.0	0.8	21035.4	9779.8	45.3	302.5	9.4	–	35.8	25.7
	JAN	–	–	7876.5	45.8	–	2800.4	2782.1	10.4	57.2	2.6	–	–	8.3
	JAH	1.1	–	1767.3	35.6	–	1658.8	1894.7	4.3	18.3	0.1	–	4.5	3.7
	AI	–	–	2886.4	11.0	–	951.8	857.4	0.5	14.2	0.3	3.1	–	1.4
	KU	–	–	1457.2	33.8	–	923.7	940.2	0.9	6.2	0.3	3.4	26.4	0.7
Nov-14	FTZ	46.0	87.8	36320.1	444.0	–	19651.9	11984.3	45.1	223.3	10.4	–	39.8	22.0
	JAN	–	–	4673.3	66.1	–	1613.5	1209.1	3.0	19.4	3.8	38.4	13.7	5.1
	JAH	16.9	19.1	21812.4	207.2	20.3	7544.7	5752.6	26.2	116.3	7.5	–	19.8	15.3
	AI	10.3	–	16197.2	82.9	–	5091.0	3908.0	16.7	68.4	2.9	44.8	–	8.4
	KU	10.0	–	12196.9	97.5	–	3873.9	3027.0	14.4	54.4	1.3	–	–	9.4
	Ave	34.0	79.8	23757.3	342.1	20.1	12642.0	9732.7	40.9	204.6	8.3	36.2	56.5	26.0
	Max	88.2	199.5	69989.1	1465.2	33.8	32692.0	24213.9	117.5	537.8	19.0	78.7	164.2	71.1
	Min	1.1	17.2	1457.2	11.0	0.8	923.7	857.4	0.5	6.2	0.1	3.1	4.5	0.7
Site (ave)	FTZ	38.7	109.9	39876.4	401.9	0.8	22357.3	12204.5	52.3	289.8	11.3	–	53.0	31.2
	JAN	34.6	56.6	12303.2	479.4	17.0	7982.2	7175.3	28.1	138.2	6.7	37.8	66.0	20.1
	JAH	39.7	96.5	31937.3	362.0	20.3	16502.4	13214.7	57.1	274.2	10.7	78.7	62.1	36.2
	AI	16.9	41.4	15615.8	145.8	32.7	7766.2	7603.3	31.8	153.0	6.4	23.9	57.7	19.9
	KU	37.0	56.3	19054.1	321.3	–	8601.7	8465.6	35.5	167.7	6.3	25.8	43.7	22.8

(–) not detected

Table 2 Correlations between the elements in dust fallout collect samples

Correlations													
	Sb	Fe	As	Mn	Mg	Zn	V	Cr	Co	Cu	Ni	Ca	Pb
Sb	1												
Fe	0.253												
As	[a]	0.783*											
Mn	0.001	0.968**	0.811*	1									
Mg	−0.163	0.909**	0.835*	0.907**	1								
Zn	0.251	0.614**	0.738	0.526*	0.618**	1							
V	0.387	0.963**	0.834*	0.923**	0.906**	0.710**	1						
Cr	0.022	0.104	0.801	0.045	0.030	0.051	0.069	1					
Co	0.035	0.764**	0.339	0.625**	0.718**	0.632**	0.819**	0.053	1				
Cu	−0.138	0.266	0.870	0.157	0.534*	0.268	0.342	0.498	0.448	1			
Ni	−0.399	0.825**	0.848*	0.914**	0.826**	0.272	0.726**	−0.050	0.356	0.043	1		
Ca	−0.027	−0.184	0.886*	−0.232	−0.253	−0.153	−0.231	0.973**	−0.148	0.397	−0.274	1	
Pb	0.030	0.951**	0.837*	0.918**	0.949**	0.664**	0.928**	0.025	0.737**	0.351	0.801**	−0.270	1

**Correlation is significant at the 0.01 level (two-tailed); *correlation is significant at the 0.05 level (two-tailed)

[a] Cannot be computed because at least one of the variables is constant

concentration shows less significant positive correlations with Ni and Zn, all of which have already been suggested to be related to automobile emission. In general, As is very strongly correlated ($r>8$) with almost all elements (except for Co) presented in Table 2.

Enrichment factor analysis

The use of enrichment factor (EF) is based on a common and conservative reference element such as Fe, Mn, and Al (Isakson et al. 1997; Lee et al. 1998; Bergamaschi et al. 2002; Mishra et al. 2004). The contents of elements in Kuwait soils were determined by Al-Awadhi and AlShuaibi (2013) by analyzing 184 top surface soil samples collected from different types of aeolian surface sediments. The comparison shows that the average concentrations for four toxic elements in the dust fallout samples, namely Zn, As, Pb, and Ni, were 18.6, 7.3, 6.5, and 3.1 times, respectively, higher than their soil background values. This implies that most pollutants in the dust fallout samples originated from anthropogenic sources. Based on the finding of Al-Awadhi and AlShuaibi (2013). Mn is considered the baseline content of the reference element (B_{ref}) in Kuwait sediments. Accordingly, the results of the EFs for the elements are presented in Table 3. Table 3 shows that the following elements have mean EFs higher than 2 with a decreasing order of their overall contamination degrees of dust in the study area: As, Zn, Pb, and Cu.

The EF can be used to understand the source of the contaminant whether it is anthropogenic or not and the degree that this contaminant can affect the environment. It has been suggested that if the EF is equal to or higher than 10, then the source of the element is anthropogenic (Lee et al. 1994; Liu et al. 2003). Accordingly, referring to the results in Table 3, elements with maximum EFs higher than 10 are As and Cu. The results also indicate that Pb (at KU site; educational area) and Zn (in light industrial area) have mean EFs higher than 5, meaning significant contamination. These elements can be emitted from burning fossil fuel, and we propose that automobile exhaust catalysts are the primary source.

The results, also, show elevated enrichment level of Pb, Zn, and As in dust fallout samples during the cold season (January and November). This may confirm that a significant portion of the pollutant is generated from vehicles, mostly due to increase of traffic movement, because of peak traffic during educational semesters. The lower average pollutant level in summer at the study area may be due to less impact of traffic volume. A factor contributing to the lower levels of dust pollution in the summer season could be associated with the fact that the majority of the population in Kuwait, especially the non-Kuwaiti professionals and labors, depart the State for summer vacation, i.e., less traffic impact.

Contamination factor analysis

The calculated results of the contamination factor, described a single element index, for each element are presented in Table 4. Based on the four categories of contamination factors defined by Hakanson (1980) and identified in Table 4, the means of the contamination factor values for Pb, Zn, and As are in very high contamination category ($CF>6$), while Zn,

Table 3 Seasonal and site enrichment factors for elements in dust fallouts in the study area

	Site	Pb	Ni	Ca	Zn	Sb	Mg	Fe	Cr	Mn	Co	As	Cu	V
Jan-14	FTZ	3.6	2.2	0.5	11.0	0.0	2.2	1.3	1.1	1.0	1.1	–	1.1	0.9
	JAN	4.0	1.7	0.2	35.1	0.7	1.6	1.5	1.2	1.0	1.3	–	1.4	1.0
	JAH	4.8	2.2	0.3	12.7		1.9	1.7	1.3	1.0	1.2	–	1.6	1.0
	AI	4.1	1.6	0.2	13.1	1.8	1.5	1.6	2.1	1.0	1.6	–	1.4	1.2
	KU	9.2	1.4	0.2	26.7		1.4	1.5	1.5	1.0	1.0	–	1.2	1.3
Apr-14	FTZ	2.9	1.4	0.5	8.0		1.6	1.2	0.8	1.0	1.1	–	0.8	0.7
	JAN	2.4	0.4	0.4	10.8	0.2	1.2	1.5	0.7	1.0	1.1	4.4	2.0	0.7
	JAH	2.2	0.6	0.5	4.6		1.1	1.1	0.7	1.0	0.8	3.5	0.5	0.6
	AI	1.0	0.4	0.4	3.6	0.6	1.0	1.3	0.6	1.0	1.0	–	0.8	0.7
	KU	1.4	0.6	0.5	6.1		1.1	1.4	0.8	1.0	1.1	2.7	0.5	0.6
Jun-14	FTZ	1.4	1.6	0.5	5.2	0.0	1.7	0.9	0.7	1.0	0.8	–	0.5	0.5
	JAN			0.9	35.3		3.6	4.4	0.7	1.0	1.3	13.3	18.0	0.7
	JAH			0.6	5.2		1.2	1.4	0.9	1.0	1.2	–	–	0.9
	AI	1.3		0.4	12.7		2.2	3.0	1.1	1.0	0.2	–	1.0	1.3
	KU		0.0	0.8	5.1		1.6	1.8	0.2	1.0	0.6	5.3	–	0.6
Nov-14	FTZ	4.7	1.8	0.7	12.9		2.1	1.6	1.0	1.0	1.3	–	0.8	0.6
	JAN			1.0	22.2		2.0	1.8	0.7	1.0	5.3	47.8	3.0	1.7
	JAH	3.3	0.8	0.8	11.6	1.2	1.6	1.4	1.1	1.0	1.7	–	0.7	0.8
	AI	3.5		1.0	7.9		1.8	1.7	1.2	1.0	1.1	15.8	–	0.8
	KU	4.2		0.9	11.7		1.7	1.6	1.3	1.0	0.6	–	–	1.1
Ave		3.4	1.2	0.6	13.1	0.6	1.7	1.7	1.0	1.0	1.3	13.3	2.2	0.9
Max		9.2	2.2	1.0	35.3	1.8	3.6	4.4	2.1	1.0	5.3	47.8	18.0	1.7
Min		1.0	0.0	0.2	3.6	0.0	1.0	0.9	0.2	1.0	0.2	2.7	0.5	0.5
Ave. site	FTZ	3.2	1.8	0.6	9.3	0.0	1.9	1.2	0.9	1.0	1.1	–	0.8	0.7
	JAN	3.2	1.0	0.6	25.9	0.5	2.1	2.3	0.8	1.0	2.2	21.8	6.1	1.0
	JAH	3.4	1.2	0.5	8.5	1.2	1.4	1.4	1.0	1.0	1.3	3.5	0.9	0.9
	AI	2.5	1.0	0.5	9.3	1.2	1.6	1.9	1.3	1.0	1.0	15.8	1.1	1.0
	KU	4.9	0.7	0.6	12.4		1.5	1.6	0.9	1.0	0.8	4.0	0.9	0.9

EF<2: deficiency to minimal enrichment; 2–5: moderate enrichment; 5–20: significant enrichment; 20–40: very high enrichment; >40: extremely high enrichment (after Sutherland 2000)

(–) not calculated because no concentration detection

Cu, Co, Cu, and V are in moderate contamination category (1 <CF<3). The data again confirm that the dust fallout sediments act as a trap for trace metals emitted either from traffic or light industrial activities. The light industrial area exhibits higher dust fallout contaminations of Pb, Zn, and As than in educational area. In general, the pattern distribution of CF values over the study area is in general agreement with pattern distribution of EF values.

Total petroleum hydrocarbon analysis

The main sources of total petroleum hydrocarbons (TPHs) are the refineries, oil transportation, and oil production (e.g., Das and Chandran 2011). According to Das and Chandran (2011), hydrocarbons are considered carcinogens and neurotoxic organic pollutants. In this study, an attempt was made to investigate the toxicity of the persistent organic contaminants in the dust fallout via measuring the TPH. The qualitative concentrations of TPHs in the dust fallout samples are presented in Table 5.

A higher mean TPH concentration is recorded in FTZ site (Free Zone Area and port area; 3239 μg/filter), while lower mean concentration is recorded in KU site (Educational area; 861 μg/filter). The elevated mean concentration of TPH in dust samples at the port area may reflect an increase in emissions associated with vessel movements and port activities. Once again, the light industrial area exhibits higher dust fallout contaminations of TPH than in educational areas, and the pattern distribution of TPH concentrations over the study area is in general agreement with pattern distribution of EF and CF values. This may indicate that while the traffic is the main source of dust pollution in the study

Table 4 Seasonal and site condemnation factors for elements in dust fallouts in the study area

	Site	Pb	Ni	Ca	Zn	Sb	Mg	Fe	Cr	Mn	Co	As	Cu	V
Jan-14	FTZ	9.4	5.7	1.3	28.4	–	0.9	3.4	2.7	2.6	2.8	–	2.8	2.2
	JAN	9.2	3.8	0.5	79.8	0.0	0.6	3.4	2.8	2.3	2.9	–	3.1	2.3
	JAH	16.9	7.9	1.2	44.9	–	1.1	5.9	4.7	3.5	4.3	–	5.9	3.7
	AI	4.5	1.8	0.3	14.6	0.1	0.3	1.8	2.3	1.1	1.8	–	1.6	1.3
	KU	14.2	2.2	0.3	41.2	–	0.4	2.4	2.3	1.5	1.6	–	1.9	2.0
Apr-14	FTZ	7.8	4.0	1.5	21.9	–	0.7	3.2	2.1	2.7	3.0	–	2.1	1.8
	JAN	4.1	0.7	0.7	18.6	0.0	0.3	2.6	1.2	1.7	1.8	7.5	3.5	1.2
	JAH	10.1	2.8	2.4	20.7	–	0.8	5.1	3.2	4.5	3.7	15.9	2.1	2.9
	AI	3.2	1.4	1.2	12.1	0.0	0.6	4.4	2.1	3.3	3.3	–	2.5	2.3
	KU	5.1	2.2	1.8	21.6	–	0.6	4.9	2.8	3.6	3.8	9.7	1.9	2.3
Jun-14	FTZ	3.6	4.2	1.3	13.1	0.0	0.7	2.4	1.8	2.5	2.1	–	1.3	1.3
	JAN	–	–	0.0	1.8	–	0.0	0.2	0.0	0.1	0.1	0.7	0.9	0.0
	JAH	–	–	0.3	2.5	–	0.1	0.7	0.4	0.5	0.6	–	–	0.4
	AI	0.2	–	0.1	1.9	–	0.1	0.5	0.2	0.2	0.0	–	0.2	0.2
	KU	–	–	0.1	0.6	–	0.0	0.2	0.0	0.1	0.1	0.6	–	0.1
Nov-14	FTZ	8.8	3.5	1.2	24.2	–	0.7	2.9	1.8	1.9	2.4	–	1.4	1.2
	JAN	–	–	0.2	3.6	–	0.1	0.3	0.1	0.2	0.9	7.7	0.5	0.3
	JAH	3.2	0.8	0.7	11.3	0.1	0.3	1.4	1.1	1.0	1.7	–	0.7	0.8
	AI	2.0	–	0.5	4.5	–	0.2	0.9	0.7	0.6	0.7	9.0	–	0.4
	KU	1.9	–	0.4	5.3	–	0.1	0.7	0.6	0.5	0.3	–	–	0.5
Ave		6.5	3.1	0.8	18.6	0.0	0.4	2.4	1.6	1.7	1.9	7.3	2.0	1.4
Max		16.9	7.9	2.4	79.8	0.1	1.1	5.9	4.7	4.5	4.3	15.9	5.9	3.7
Min		0.2	0.7	0.0	0.6	0.0	0.0	0.2	0.0	0.1	0.0	0.6	0.2	0.0
Ave. Site	FTZ	7.4	4.3	1.3	21.9	0.0	0.8	3.0	2.1	2.4	2.6	–	1.9	1.6
	JAN	6.6	2.2	0.4	26.0	0.0	0.3	1.6	1.0	1.0	1.4	5.3	2.0	1.0
	JAH	10.1	3.8	1.1	19.9	0.1	0.6	3.3	2.4	2.4	2.6	15.9	2.9	2.0
	AI	2.5	1.6	0.5	8.3	0.1	0.3	1.9	1.3	1.3	1.4	9.0	1.4	1.1
	KU	7.1	2.2	0.7	17.2		0.3	2.1	1.4	1.4	1.4	5.2	1.9	1.2

CF<1: low contamination factor indicating low contamination; 1<CF<3: moderate contamination factor; 3<CF <6: considerable contamination factor; 6<CF; very high contamination factor (after Hakanson 1980)

(–) not calculated because no concentration detection

area, upstream/downstream industries such as power stations and oil fields/refineries contribute least to air pollution emissions in the area; i.e., the emissions of TPH pollutant from the oil fields and petrochemical industries are also possible sources in the vicinity of the study area, and its surroundings. The seasonal variation in TPH levels, i.e., elevated levels in September and December samples, could be associated with two dominant prevailing wind directions in Kuwait, namely NW during dry season and SW during cold season, that

Table 5 TPH concentrations (μg/filter) in dust fallout samples in the study area

		TPH (Mar-14)	TPH (Jun-14)	TPH (Sep-14)	TPH (Dec-14)	Ave.
Site	FTZ	2007	1597	4547	4804	3238.75
	JAN	1718	497	873	724	953
	JAH	624	1109	2052	823	1152
	AI	789	908	824	394	728.75
	KU	634	908	782	1122	861.5
	Ave	1154.4	1003.8	1815.6	1573.4	

transport pollutants, including TPH, from oil fields towards Kuwait City and its surroundings.

Conclusions

The results show that (1) a major source contribution of dust particles to the port area is excessive traffic of heavy trucks and ongoing road constructions; (2) the enrichment factor and contamination factor indicate that the fallout sediments are significantly contaminated by As, Zn, and Pb with the following distribution order As > Zn > Pb, while the concentrations of these elements showed higher values than their local background values in the following distribution order Zn > As > Pb; (3) the TPH results show significant elevation in concentration among all collected samples through the months of September and December, and the reason may be associated with the prevailing wind directions, transporting pollutants from northern and southern oil fields towards the study area; and (4) the overall findings of this study reflect the enrichment of pollution in the dust fallout sediments, which is associated mainly with traffic load and pollution.

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