Assessment of particle pollution in an industrial area in Kuwait

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Abstract

Particles less than 10 μm in diameter, which are named as respirable particle (RPM) by the OSHA have very low sedimentation speeds under gravity, and may remain in the air for days before eventually being washed out by rain or impacted out onto vegetation or buildings. RPM are a very important environmental pollutant, which can causes visibility, surface soiling, and health problems. Therefore, it is necessary to find concentrations of the RPM in ambient and working places. This paper will discuss a study of PM10, PM2.5 and RPM in an industrial area of Kuwait. This area houses several construction material industries such as cement bricks, marble products, paving products etc. Due to the industrial nature, an intensive amount of dust is generated in the confined working environment. The sampling sites included indoor and outdoor areas. Sampling periods were from cold to hot weathers. Thus, comparisons under different weathers, different locations, and in-out doors can be made.
Keywords: air pollution, PM10, PM2.5, respirable particle, health effect.

1 Introduction

There are many particles floating around in the air, some of which cannot even be seen. Particles can be solid particles or liquid droplets. They are ranged from 0.1 to 50 μm which are called total suspended particles (TSP). The small particles less or equal to 10 μm can be further divided into two major groups according to sizes: coarse particles (PM10) and fine particles (PM2.5). Particles less than 10 μm in diameter tend to pose the greatest health concern because they

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can be inhaled into and accumulate in the respiratory system. Therefore, it is necessary to find the size distribution and concentration of the particles (less than 10 μm) in air.

Maximum limit allowance for occupational exposure to particulates set up by Kuwait EPA is 5 mg/m^3 for respirable dusts, which are less than 10 μm (RPM) [1]. The standard for nuisance dusts from US Occupational Safety & Health Administration (OSHA) [2] is also 5 mg/m^3. The conditions for the OSHA standard are limited as the particles containing no asbestos and quartz less than 1% and penetrating non-ciliated portions of respiratory system.

The Clean Air Act (CAA) in US was passed in 1970, and the National Ambient Air Quality Standard (NAAQS) was established. In the NAAQS, TSP was one of the 7 criteria pollutants. The USEPA standard for particle matter changed from TSP to PM10 in 1987. PM2.5 was subsequently added to the new standard in addition to PM10 in 1997. PM2.5 is a subset of PM10. The PM10 is classified as inhalable fine particulate matter by USEPA [3].

The USEPA air quality index (AQI) for particle matter includes both PM10 and PM 2.5 (see Figure 1) [3]. It should be noticed that the definition for inhalable particle is different between USEPA and Kuwait EPA. The Kuwait EPA definition for inhalable particles is particles whose diameters are large than 10 μm.

US EPA continuously renews the NAAQS standard. Particles less than 2.5 μm have gained more and more attention. The unhealthy levels (AQI > 151) can provide more information for assessing the health problems caused by dusts in air.

An industrial area is located northwest of Kuwait city. It houses several small construction material industries such as cement bricks, marble and granite cutting and polishing and paving products. Due to the nature of this type of industry, intensive amount of dust is generated in the confined working environment (Figure 2). Most, if not all, of the work are conducted manually. Therefore, labours may be exposed continuously to high level of dust in the work surroundings. According to an internationally accepted respiratory tract model [4], inhaled particles larger than 10 μm (micron) will be cleared from the lungs by mucociliary action, swallowed, and eventually reach the gastrointestinal tract, whereas, particles less than 10 μm can be deposited in the respiratory systems. The accumulation of such particulates due to continuous and long time exposure can lead to an increase of the level of pollutants and radioactive materials in the respiratory system and other body organs, accordingly leading to severe adverse health effects. Although heavy metals are not attracted to single biological compound, previous research has demonstrated that they have toxic effects on specific organs in the body. For this reason limits were implemented on toxic elements and compounds by Law No. 21 of 1995 in Kuwait [1], and a special attention has also been paid to the composition of building materials [5,6].

The US EPA AQI related to PM10 and PM2.5 concentrations are listed in Table 1.

Several ambient air pollution studies have been conducted by Kuwait EPA, Kuwait Institute for Scientific Research, Kuwait University, and other private

companies; however air pollution in the working environment need more investigations. Since Kuwait Environmental Protection Agency (EPA) has issued the environmental regulation in October 2001 (Maximum Limits Allowance Table for Biological Effect – as a result of occupational exposure to chemical substances), it is essential to investigate the particles related environmental problems in more details, in Kuwait.

Table 1: AQI and PM concentration.

AQI	PM2.5 $\mu g/m^3$	PM10 $\mu g/m^3$
0-50	0.0-15.4	0-54
51-100	15.5-40.4	55-154
101-150	40.5-65.4	155-254
151-200	65.5-150.4	255-354
201-300	150.5-250.4	355-424
301-500	250.5-350.4	425-504
>500	350.5-500.4	505-604

Index Values	Levels of Health Concern	Cautionary Statements
0-50	Good	None
51-100*	Moderate	Unusually sensitive people should consider reducing prolonged or heavy exertion.
101-150	Unhealthy for Sensitive Groups	People with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion.
151-200	Unhealthy	People with heart or lung disease, older adults, and children should avoid prolonged or heavy exertion. Everyone else should reduce prolonged or heavy exertion.
201-300	Very Unhealthy	People with heart or lung disease, older adults, and children should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy exertion.
301-500	Hazardous	People with heart or lung disease, older adults, and children should remain indoors and keep activity levels low. Everyone else should avoid all physical activity outdoors.

Figure 1: US EPA AQI for particulates and health caution.

Figure 2: A workshop of a marble company in the AIA.

This paper includes PM10, PM2.5 and RPM collected and analyzed in 15 stations in the industrial area. The results have been compared to OSHA, Kuwait EPA and US EPA standards. Health effects to human beings by particle matters have been assessed.

2 Experiments

2.1 Field sampling locations

The design of this study includes comparison of PM10 and PM2.5 particles in concentrations between indoor and outdoor at the same location, outdoor and outdoor at different locations, indoor and indoor at different locations, and working and no working periods at different locations. 15 stations have been selected, which included marble company, block company, asphalt company etc. A location close to a mosque was selected as an ambient station for reference purpose.

2.2 Field sampling

Dichotomous samplers (Model 241, Andersen Instruments, Inc. Atlanta, GA USA) were used in this study. These instruments meet all the USEPA federal reference method performance specifications for the measurement of PM10 and PM2.5 [7]. Figure 3 shows a Dichotomous sampler in a block workshop.

Here, we have to emphasize that there are many semi-volatile compounds in the atmosphere which exist in particle phase [8]. These particles are easily lost during sampling. The Dichotomous sampler cannot collect those semi-volatile compounds. Therefore, the quantifications of the total particles (PM10 and PM2.5) have errors. At this moment, we cannot determine the size of the error.

Figure 3: A Dichotomous sampler in a block workshop.

2.3 Laboratory studies

The collected Teflon filters were return to laboratory for quantitative measurements of particle phase by a new Toledo balance (detection limit 0.1 μg). The metal contents and radionuclide elements were measured by an ICP and a gamma-spectrometer.

3 Results and discussions

3.1 Mosque location (Station 1)

As discussed above, the location close to a mosque was used as an ambient station to evaluate the particulate air pollution in the industrial area; and as a reference station to find the possible relation to the working places. The sampling period was from January to June 2005. In Kuwait, January and February are normal cold and relative hot in May and June. The study period generally covered the Kuwait climatic partner.

Figure 4 is a comparison of PM2.5, PM10, and the Kuwait RPM Standard. The "Quality" column is used to compare the measured RPM results and the Kuwait EPA standard for industrial area, which is 350 $\mu g/m^3$. It can be seen that more than 70% of the measured RPM were exceeding the Kuwait ambient standard for industrial areas. According to Kuwait EPA regulation, exceedance of daily average can only occur once per year. Therefore there is no doubt that the particle pollution in this industrial area is a very serious problem. At this moment, Kuwait does not have a PM2.5 standard. US EPA's standard is 40 $\mu g/m^3$ for 24 hours. If using USEPA standard as a tool, it can be seen that the exceedance of PM2.5 is also very high in this industrial area.

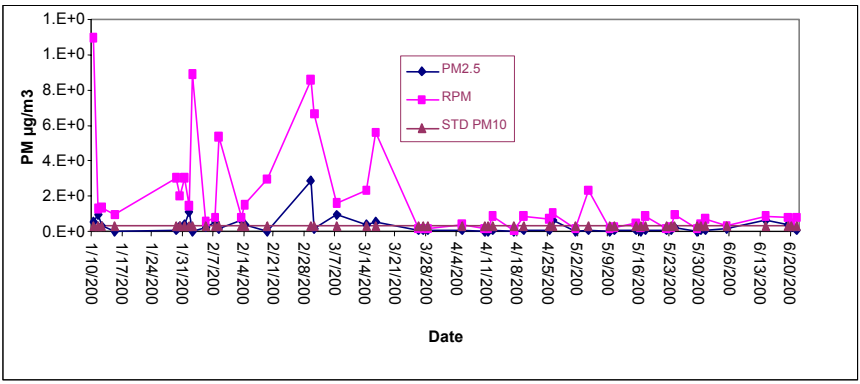

Figure 4: Comparisons of RPM and PM2.5 collected in the Station 1 with Kuwait PM10 standard.

3.2 Particulate matter in a block manufacture company (Station 2)

The product of this company is blocks. Sand and cement are the major materials used for the manufacture. We installed two samplers inside and outside the workshop. The workshop is semi-closed, which means there is an open-door in front of the workshop. There will be air exchange between outdoor and indoor airs, but not substantially. There are traffics in the front yard and a mixing machine for the sand and cement with water.

The outdoor sampler was used to monitor the ambient air in the front yard of the manufacturer to compare the air quality inside the workshop and the mosque location.

Table 2 lists the 24-hour measurement results for the indoor and outdoor. It is observed that the indoor concentrations of RPM were sometime higher and sometime lower than the outdoor, which indicates that the dusts concentrations are depended on human activities. For example, more traffic in the front yard might generate more dusts. Thus the average RPM concentrations outside the workshop sometimes were higher than inside. However, the overall average RPM concentrations inside were higher than outside due to the confined situation inside.

As discussed above, the measurement periods were 24 hours in the above study. If using USEPA AQI standard to evaluate the health effects in the above studies, it can be clear seen that except March 26th and April 5th measurement outdoor, all other RPM concentrations were in the “Hazardous” range, which requests that everyone should avoid all physical activity in this air polluted condition.

We also conducted working and non-working hours study in this location. The study results will be discussed in another section.

The comparison of RPM concentrations measured in the Station 1 and 2 is shown in Figure 5. Generally speaking, there is no doubt that the ambient particle pollution will affect the outside concentration in Station 2. When the

ambient RPM concentrations were high, the RPM concentrations outside the workshop were high. However, the outside RPM concentrations were also governed by the human being activities in the front yard. That is why sometime the outside RPM concentrations in Station 2 were higher than in Station 1.

Table 2: Particulate matter in the Al-Ayoub Company of Constitutive Materials.

Date	Outdoor µg/m^3		Indoor µg/m^3	
	PM2.5	RPM	PM2.5	RPM
12-Jan	114	2955	176	2231
15-Jan	164	7614	23	5925
31-Jan	249	1115	314	2950
2-Mar	159	1033	494	3760
7-Mar	1843	2391	1035	2511
16-Mar	660	3148	586	2477
26-Mar	6	32	42	1311
5-Apr	94	174	149	7601
Average	411	2307	352	3596

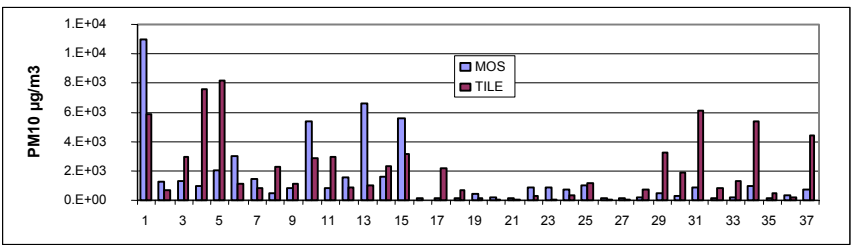

Figure 5: RPM concentration comparison between Station 1 (Mosque) and outside Station 2 (block company).

3.3 Particle matter in working and non-working hours

Particle matter in working and non-working hours were measured in most stations. Table 3 lists the measurement results. According to Kuwait EPA standard for working place, it can be observed that several manufacturers had exceeded the standard. But if using USEPA AQI as a tool to assess the particulate pollutants, it can be observed that most working places had significant health problems.

The RPM comparisons for working and non-working hours are shown in Figure 6. Generally, the RPM and PM2.5 concentrations during working hours were higher than the non-working hours. But, in several locations, it was via verse. It is noticed that these locations had large open place between indoor and outdoor, wind could easily blow dusts between indoor and outdoor, which might be the reason for the higher dust concentrations in non-working hours.

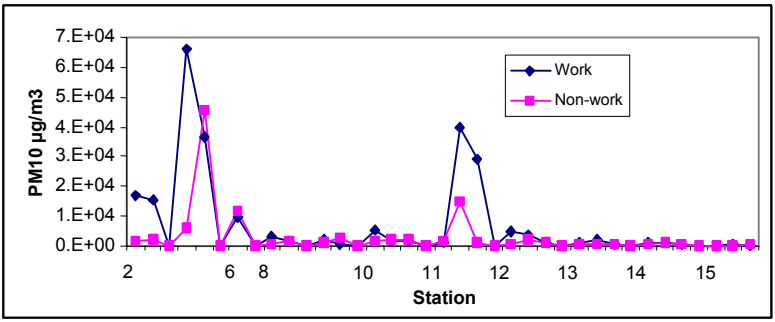

Figure 6: Comparison of RPM during working hours and non-working hours.

Table 3: Working place particle matter in Kuwait.

Station	Working Hours µg/m^3		Kuwait EPA	Non-working Hours µg/m^3		RPM 24 Hour	AQI
	PM2.5	RPM	WTA	PM2.5	RPM	Average	Category
2	486	16736	Exceed	38	1418	5901	Hazardous
	837	15437	Exceed	299	2079	12098	Hazardous
5	24000	66190	Exceed	322	5602	23141	Hazardous
	816	36816	Exceed	123	45758	43236	Hazardous
6	102	9384	Exceed	290	11599	10468	Hazardous
8	150	3221		39	789	1619	Hazardous
	43	1754		69	1552	1623	Hazardous
9	32	1915		25	1063	1354	Hazardous
	15	734		92	2822	2091	Hazardous
10	89	5081	Exceed	60	1414	2954	Hazardous
	29	1574		49	1924	1817	Hazardous
	32	1573		48	2056	1912	Hazardous
11	44	1038		88	1772	1478	Hazardous
	490	39778	Exceed	80	14913	22825	Hazardous
	470	29333	Exceed	437	1095	10080	Hazardous
12	143	4747		30	688	2183	Hazardous
	85	3468		118	2202	2681	Hazardous
	37	1321		49	1272	1286	Hazardous
13	32	1257		14	493	827	Hazardous
	44	2306		152	481	1279	Hazardous
	86	424		17	463	446	Hazardous
14	50	850		25	733	778	Hazardous
	40	1223		26	837	985	Hazardous
	19	707		25	731	722	Hazardous
15	120	202		126	129	147	
	410	443		76	156	218	
	20	20		398	423	335	Un-health

As it is well known that PM10 particles can stay in the air for minutes or hours while PM2.5 particles can stay in the air for days or weeks that is why we can find in many cases that the PM2.5 concentrations have no substantial difference between working hours and non-working hours.

3.4 Metal contents and radionuclide elements in the particles

The following metals were identified and measured in the industrial area: Cr, Fe, Ni, Pb, and Zn. It is observed that several locations had a few higher concentrations for Fe, Zn, Ni and Pd. Basically; metals are not substantial problems in the industrial area.

Many natural radionuclide elements have been identified in the samples, which include Be-8, Pa-234m, Pb-214, Th-234, K-40, Ra-226, Bi-211 etc. Fortunately the radiation was very low. Based on many standards, it is safe to say that the natural radiation in the industrial area has no significant health impact to human health.

4 Conclusions

Ambient RPM concentration is a serious problem in the industrial area of Kuwait. It requires a comprehensive plan to improve the ambient air quality in this area. Respirable dusts in the working place were different from manufacturer to manufacturer. According to Kuwait EPA standard for the working places, it was found that several locations had exceedances in the study period. But if using USEPA AQI standard as an assessment tool, the problems of dusts in the working places need to be carefully considered. A review meeting for the particulate matter in air is needed in order to clear confusions in definition and to determine the proper limitations in Kuwait.

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