ASSESSMENT OF SUSPENDED PARTICULATE MATTERS LEVEL AND ROLE OF VEGETATION IN AMBIENT AIR OF NORTH-EAST BALOCHISTAN, PAKISTAN

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Abstract

The present study was conducted to investigate the distribution of respire-able (RSPM) and total suspended particulate matter (TSPM) in the ambient air of north-east Balochistan (Quetta, Zhob and Loralai), Pakistan. The samples were collected by standard methods for a period of one year (2012). Observation exhibited that at Quetta city the annual average contents of RSPM& TSPM ranged from 238-661.5µg/m^3& 3984.5-5210.5µg/m^3 in residential (non-green) areas, where as in green belt areas of the same city it was 70-451µg/m^3 to 2037-3340.5µg/m^3. In Zhob city the annual average values of RSPM & TSPM in residential (non-green) areas was ranged from 200.5-477µg/m^3& 2743-3113µg/m^3, while in green belt area it was found from 74.5-357µg/m^3 to 1726-2194.5µg/m^3. The atmosphere of Loralai city exhibited 135-383µg/m^3 for RSPM and 1826.5-2150µg/m^{3}for TSPM at residential (non-green) area, whereas in green belt area it was 71.5-346µg/m^3 to 1374-1700.5µg/m^3. The 24–h TSPM and RSPM levels measured during the current study were found to be significantly higher than WHO and USEPA standard values. Present study also revealed that TSPM & RSPM values in green belt areas of all three investigated cities are increasing. But in the residential areas, as there is no particulate emission control the level of SPM are in critical level. Among the investigated cities the decreasing trend of average particulate matters (TSPM and RSPM) revealed the following order: Quetta >Zhob>Loralai.

Introduction

Airborne particulate matter, which includes dust, dirt, soot, smoke, and liquid droplets emitted into the air, are small enough to be suspended in the atmosphere. Airborne particulates may be a complex mixture of organic and inorganic substances. They can be characterized by their physical attributes, which influence their transport and deposition, and their chemical composition, which influences their effect on health. In the atmosphere, these metals are release by both natural and man-made activities (Harrison, 1999), although the latter are predominant in the urban and industrial areas (Borbely–Kiss *et al.,* 1999; Pakkanen *et al.,* 2001).Some of the well known anthropogenic processes contributing to the airborne particulate pollution include transportation, industrial activities, biomass burning and agricultural activities (Harrison *et al.,* 1997;Hien *et al.,* 2001; Arditsoglou and Samara, 2005; Valavanidis *et al.,* 2006). There is an increasing concern about the hazardous effects of atmospheric pollutants on humans and other living organisms in populated areas (Freitas *et al.,* 2010; Garcia *et al.,* 2011).These metals are eventually removed through a deposition on the aquatic and terrestrial ecosystems (Harrison, 1999). Atmospheric total suspended particulate matter (TSPM &RSPM) has been linked with a number of environmental and human health effects on regional and global scales (Wallenborn *et al.,* 2009; Seinfeld and Pankow, 2003).

Many monitoring programs on atmospheric particulate matter have been conducted in several parts of the world which showed diverse fluctuations and disparities among the particulate matter and trace element constituents (Sohrabpour *et al.,* 1999; Bilos *et al.,* 2001;Rizzio *et al.,* 2001a; Wang *et al.,* 2001; Ragosta *et al.,* 2002; Quiterio *et al.,* 2004a; Gupta *et al.,* 2007; Hao *et al.,* 2007; Ayrault *et al.,* 2010). Recently many researchers like Andersen *et al.,* (2006); Sarnat *et al.,* (2006); Liu *et al.,* (2009); Mavroidis and Chaloulakou, (2010) pointed out that airborne particulates containing toxic components, such as heavy metals, are of special concern due to numerous health effects.

Balochistan is the largest Province of Pakistan, situated on the southwest and covers an area of 134,051 mi^2 or (347,190 km^2), thus constituting 44% of Pakistan's total land mass (Balochistan Encyclopedia, 2009). The Balochistan is bordered with Afghanistan to the north and northwest, Iran to the southwest, Punjab and Sindh to the east, and Khyber Pakhtunkhwa (KP) and the Federal Administrated Tribal Areas to the northeast. To the south lies the Arabian Sea. Balochistan is a land of varieties. It has mountains like Chiltan, Takatu, Sulaiman, Sultan etc. and plains stretching hundreds of miles.

The present study was undertaken in order to assess the level of atmospheric particulate pollution and to estimate the role of green belts (vegetation's) to minimize these particulate maters in major cities of north-east Balochistan (Quetta, Zhob and Loralai), Pakistan.

Materials and Methods

This study was conducted during summer and winter season of 2012in three major cities (Quetta, Zhob and Loralai) of north-east Balochistan, Pakistan. For the Sampling of Suspended Particulate Matter (SPM) two sampling areas in each city were selected for the study: Four stations were chosen from residential and commercial(non-green) areas and Four were selected from green belt area of the same each city. The sampling areas were selected, where activities of human and vehicles are prevalent. The sampling apparatus was sheltered from any direct rain and kept at a height of 2-3m from the surface of the ground (Mueller and Smith, 1991). Airborne SPM was measured with the help of Respire-able Dust Sampler (RDS), APM 460 by sucking air into appropriate reagent for 24 hour at every 30 days interval. The Particulate Matter were analyzed using Respire-able Dust Sampler (RDS) PM 460 operated at an average flow rate of 1.0 – 1.5m^3 $min^{-1.}$ Pre-weighed glass fiber filters (GF/A) of Whatman were used as per standard methods. The concentration of SPM was measured by standard modified method of West and Gaeke, (1956), Jacobs-Hochheiser, (1958) and Rao and Rao, (1998).

Statistical analysis: The standard deviation values of the means were calculated for comparison of site categories. To determine the significance of the samples, paired t-test was performed (Steel & Torrie, 1980).

Results and Discussion

All the parameters pertaining to the distribution of airborne particulate matters (TSPM and RSPM) are given in Table 1-4. The 24–h suspended particulate matters levels in urban residential (non-green) areas and in green belt areas of the same city showed a random distribution.

During summer season the mean concentrations of airborne TSPM and RSPM at residential area exhibited5340.8, 3735.8, 2355.0µg/m^3 and649.3, 449.3, 342.5µg/m^3 for Quetta, Zhob and Loralai, respectively (Table 1).When the present data were compared with the green belt area of the same city, a significant decrease concentration of TSPM and RSPM was noted. That was found 3423.8, 2524.8, 1791.8µg/m^3 for TSPM and405.5, 314.0, 311.3µg/m^3 for RSPM in the atmosphere of Quetta, Zhob and Loralai, respectively (Table 1).Decrease percentage of TSPM in green belt area with respect to residential area during summer season was56.0, 48.0, 31.4%, while for the RSPM it was noted60.1, 43.1, and 10.0% in Quetta, Zhob and Loralai, respectively (Table 2).This decrease concentration of SPM in the green belt area might be due to presence of vegetation, which capture the particulate matter before reaching ground surface. A review of the literature reveals considerable evidence to support the suggestion that vegetative surfaces remove particulate matter from the atmosphere. The hypothesis that plants are important particulate traps is supported by evidence obtained from studies dealing with radioactive, trace element, pollen, spore, salt, precipitation, dust and unspecified particles. Smith and Staskowicz, (1977) provide a more complete review. Smith, (1974) estimated that the leaves and current twigs of a 30 cm (12 inch) diameter urban sugar maple remove from the atmosphere 60, 140, 5800 and 820 mg of cadmium, chromium, lead and nickel respectively during the course of a single growing season. Numerous additional studies employing dust, synthetic or unspecified particles have contributed to our understanding of particulate capture by vegetation.

When the summer season data were compared with the winter season of the same cities, a significant decrease concentration of TSPM and RSPM was noted. During winter season the mean concentration of airborne TSPM at residential area was observed 4187.5, 2063.5, 1645.8µg/m^3, while RSPM was found548.0, 408.5, 325.0µg/m^3in the atmosphere of Quetta, Zhob and Loralai, respectively (Table 1). But at green belt area of Quetta, Zhob, Loralai the values of TSPM during winter season was found3156.3, 1701.5, 1485.8, while RSPM was 415.3, 333.0, 315.3µg/m^3, respectively (Table 1).Decrease percentage of TSPM during winter season at green belt area with respect to residential (non green) areas of the same cities exhibited 32.7, 21.3, 10.8%, while RSPM showed 32.0, 22.7, 3.1% for Quetta, Zhob and Loralai, respectively (Table 2).

Less decrease percentage of TSPM and RSPM in green belt areas during winter as compared to summer season might due to fall of leaves. Maiti, (1993) reported that the Leaves are susceptible and highly exposed parts of a plant, may act as persistent absorbers in a polluted environment. Further that the high concentration of particulate mater during summer with respect to winter season might be due to high mobility of traffic and human activities.

Table 1. Average concentration of Air borne particulate matter and their maximum and minimum values during different season in investigated cities.

Sampling site	Summer		Winter		Annual Average	
	RSPM	**TSPM**	**RSPM**	**TSPM**	**RSPM**	**TSPM**
Quetta			**Residential (non-green) area**			
Ave	649.3 ±72.5	5340.8±568.6	548.0 ±54.0	4187.5 ±363.0	598.6 ±52.6	4764.1±464.4
Max	721	5860	602	4561	661.5	5210.5
Min	321	4380	155	3589	238	3984.5
			Green Belt area			
Ave	405.5±42.1	3423.8±49.6	415.3±40.7	3156.3±52.4	410.4±41.4	3290.0±51.0
Max	447	3473	455	3208	451	3340.5
Min	66	2074	74	2000	70	2037
Zhob			**Residential (non-green)area**			
Ave	449.3±43.6	3735.8±253	408.5±54.5	2063.5±27.5	428.9±49.0	2899.6±133.8
Max	492	4123	462	2103	477	3113
Min	278	3452	123	2034	200.5	2743
			Green Belt area			
Ave	314.0±37.3	2524.8±111	333.0±30.4	1701.5±39.8	323.5±33.8	2113.1±73.7
Max	351	2635	363	1754	357	2194.5
Min	60	1805	89	1647	74.5	1726
Loralai			**Residential(non-green) area**			
Ave	342.5±50.4	2355.0±197	325.0±49.5	1645.8±43.8	333.8±50.0	2000.4±120.6
Max	392	2580	374	1720	383	2150
Min	158	2045	112	1608	135	1826.5
			Green Belt area			
Ave	311.3±31.6	1791.8±42.6	315.3±35.8	1485.8±54.3	313.3±33.6	1638.8±37.7
Max	342	1833	350	1568	346	1700.5
Min	63	1420	80	1328	71.5	1374

Ave; Average, Max; Maximum, Min; Minimum, RSPM; Respire able Suspended Particulate Matter less than 10 microns in aerodynamic diameter , TSPM; Total Suspended Particulate Matter

Table 2. Over all average concentration of RSPM and TSPM with Decrease percentage (%) in green belts area as compared to residential (non-green) area of the same city during different seasons.

Sampling Sits	**Quetta**		**Zhob**		**Loralai**	
			Summer			
	RSPM	**TSPM**	**RSPM**	**TSPM**	**RSPM**	**TSPM**
Residential(non-green) area	649.3	5340.8	449.3	3735.8	342.5	2355.0
Greenbelt area	405.5*	3423.8*	314.0*	2524.8*	311.3*	1791.8*
Decreasing %	60.1	56.0	43.1	48.0	10.0	31.4
			Winter			
Residential (non-green) area	548.0	4187.5	408.5	2063.5	325.0	1645.8
Green belt area	415.3*	3156.3*	333.0*	1701.5*	315.3n.s	1485.8*
Decreasing %	32.0	32.7	22.7	21.3	3.1	10.8
			Annual Average			
Residential (non-green) area	598.6	4764.1	428.9	2899.6	333.8	2000.4
Green belt area	410.4*	3290*	323.5*	2113.1*	313.3*	1638.8*
Decreasing %	45.9	44.8	32.6	37.2	6.5	22.1

RSPM; Respire able Suspended Particulate Matter less than 10 microns in aerodynamic diameter, TSPM; Total Suspended Particulate Matter, *; significant ($p<0.05$) and n.s; non significant

Table 3. Summary of Air borne particulate matter and their comparison with other urban areas around the world.

Study Cities		
	RSPM	**TSPM**
Quetta	598.6	4764.1
Zhob	428.9	2899.6
Loralai	333.8	2000.4
Other Major Cities of Pakistan		
Islamabad	520.00	1614
Rawalpindi	709.00	
Lahore	607	-
Gujranwala	-	2756
Faisalabad	550	3074
Metropolitan Cities Around the World		
Dehli, India	546	-
Mumbai, India	134	-
Beijing China	496	-
Yakohama, Japan	34.2	-
Cartagena, Spain	200	-
Bilboa, Spain	171	-

RSPM: Respire-able Suspended Particulate Matter less than 10 microns in aerodynamic diameter**, TSPM:** Total Suspended Particulate Matter

Table 4. Reference standards and guidelines for average ambient particulate concentration (micrograms per cubic meter)

Standards or Guidelines	**Long –Term (Annual)**			**Short-Term (24 Hours)**		
	RPSM	**BS**	**TSPM**	**RPSM**	**BS**	**TSPM**
EU limit values (1992)		80	150		250	300
EU guideline values		40-60			100-150	
USEPA Primary And Secondary Standards (1992, 2002)	50-60			150		
WHO guidelines (1979, 2000)		40-60	60-90		100-150	150-230
WHO guidelines for Europe	50		70	125	120	

Notes: RPSM; Respire-able Suspended Particulate Matter less than 10 microns in aerodynamic diameter, BS; Black smoke converted in to µg/m^3 measure, TSPM; Total Suspended Particulate Matter
Sources: European community1992, (EU); united states, CFR (USEPA), WHO 1979 (WHO guidelines); WHO 1987 (WHO guidelines for Europe)

Because the climate of study area is arid with cold winter, moderate to hot summers (Qadir, 1968), therefore during winter all kind of activities are reduced. In contrast to the present study Spirtas and Levin (1971) reported the higher level of atmospheric particulate matters in the winter relative to the summer in urban areas. Annually decrease percentage of TSPM and RSPM at green belt areas exhibited 44.8, 37.2, 22.1% and 45.9, 32.6, 6.5% in Quetta, Zhob and Loralai respectively (Table 2). Among the investigated cities the decreasing trend of particulate matters (TSPM and RSPM) revealed the following order: Quetta > Zhob > Loralai. Higher level of particulate matter at Quetta might be due to high traffic density, large scale of small industries. All the atmospheric particulate elements were found to spread over several orders of magnitude, as shown by their respective ranges. The present data on airborne particulate are also compared with the international guidelines as well as with the counterpart data from other sites around the world as shown in Table 3. Average TSPM & RSPM levels in the atmosphere of Quetta were significantly higher than those reported from Islamabad, Gujranwala and Faisalabad (Awan, *et al.,* 2011),Yokohama (Khan *et al*., 2010), Dehli, India (Shridhar *et al.,* 2010), Mumbai, India (Taripathi *et al.,* 2004), Beiging, china (Wang *et al.,* 2001), Cartagena (Moreno–Grau *et al.,* 2000), Bilbao (Aranguiz *et al.,* 2002), Delft (Wang *et al.*,2001), Tito Scalo (Ragosta *et al.,* 2002), Ho Chi Minh City (Hien *et al.,* 2001) and Santa Cruz (Quiterio *et al.,* 2004a), while the present levels

were substantially lower than those reported from Lahore (Harrison *et al.,* 1997)and Rawalpindi (Awan *et al.,* 2011) (Table 3).

In the atmosphere of Zhob city average RSPM & TSPM levels were significantly higher than those reported from Mumbai, India (Tripathi *et al.,* 2004), Yokohama (Khan *et al.,* 2010), Cartagena, Spain (Moreno–Grau *et al.,* 2000) and Bilbao, Spain (Aranguiz *et al.,* 2002), while the present levels were substantially lower than those reported from Lahore (Harrison *et al.,* 1997), Islamabad, Gujranwala, Faisalabad, Rawalpindi (Awan *et al.,* 2011), Beijing (Wang *et al.,* 2001) and Dehli, India (Shridhar *et al.,* 2010) (Table 3).

Average RSPM levels in the atmosphere of Loralai were significantly higher than those reported from Mumbai, India (Tripathi *et al.,* 2004), Yokohama, Japan (Khan *et al.,* 2010), Cartagena, Spain (Moreno–Grau *et al.,* 2000) and Bilboa, Spain (Aranguiz *et al.,* 2002), while the present levels were substantially lower than those reported from Lahore (Harrison *et al.,* 1997), Islamabad, Gujranwala, Faisalabad and Rawalpindi (Awan *et al.,* 2011), Beijing (Wang *et al.,* 2001) and Dehli, India (Shridhar *et al.,* 2010) (Table 3). The 24–h TSPM and RSPM levels measured during the current study were found to be significantly higher than WHO and USEPA standard values (WHO, 2000; ATSDR, 2002) (Table 4). A number of health related problems may thus be associated with elevated TSPM and RSPM concentrations in the atmosphere.

Conclusions

After a short discussion it is concluded that present study revealed elevated 24–h RSPM and TSPM concentrations. Which were significantly higher than the levels of regulatory agencies. Among the selected cities, highest concentration of airborne particulate maters was noted for Quetta followed by Zhob and Loralai. The estimated airborne particulate maters concentrations in the present study were higher (in Quetta) than the other cities of same country and than in the most cities of other developing and developed countries of the world; however, these contents were lower (in Zhob and Loralai) than large metropolitan cities of the same country and cities of the other world. The present study also revealed that vegetative surfaces remove a considerable amount of particulate matter from the atmosphere. The Green Belt/Urban Forest in vicinity of Residential; Road Sides and Industrial areas, may be the option for control of particulate matter in environment around residential areas/industrial area, since trees can act as efficient biological filters, cost effectively removing significant amounts of particulate pollution from urban atmosphere. Therefore it is suggested that green belt in urban areas of the cities should be established and pollution tolerant tree species can be used for pollution free environment.

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