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Health risks for population living in the neighborhood of a cement factory

Syed Sana Mehraj[1], G. A. Bhat[1], Henah Mehraj Balkhi[2]* and Taseen Gul[2]

[1]Department of Environmental Science, University of Kashmir, J&K 190006, India.
[2]Department of Biotechnology, University of Kashmir, J&K 190006, India.

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In order to assess the health risks associated with the manufacturing of Portland cement for the population living in the neighborhood of a cement industry in Khrew, Kashmir, India, particulate matter and trace gas samplings were done between March and December 2011 in the cement affected area. The main parameters considered for study included suspended particulate matter (SPM), respirable suspended particulate matter (RSPM), non-respirable suspended particulate matter (NRSPM), nitrogen oxides (NOx) and sulfur dioxide (SO_2). The population considered most suitable for study was the people residing in 2 - 3 km radius of the cement emission zone and for this, questionnaire based study was performed. The air temperature, air humidity, wind speed, wind direction and light intensity were studied at the sites for the sampling days. The results indicate that there was high level of air pollution with mean SO_2 concentration of 115.2 μg/m^3 at site I and 28.13 μg/m^3 at site II when compared. Similarly, NOx concentration at site I was 117.09 μg/m^3 when compared with control site II where it was found to be 19.46 μg/m^3 with high prevalence of diseases particularly, respiratory problems, 97% suffered from eye irritations and 95% suffered from dermatological problems among population living in the neighborhood of cement factory at site I. The assessment of oxidative and nitrosative stress among population was carried out by quantification of ROS and NO levels in serum of subjects. The results show that there was high level of air pollution in the area, adverse health impacts, over production of nitrogen species as well as ROS in subjects residing around cement pollution affected area.

Key words: Cement industry, trace gas samplings, human health, dermatological, respiratory problems, eye irritations.

INTRODUCTION

Different industrial activities degrade various environmental components like air, soil, water and vegetation (Dolgner et al., 1983; Sai et al., 1987; Mishra, 1991; Murugesan et al., 2004; Kumar et al., 2008). Cement industry is one of the 17 most polluting industries listed by the central pollution control board of India. It is the major source of particulate matter, SOx, NOx and CO_2 emissions. Cement dust contains heavy metals like chromium, nickel, cobalt, lead and mercury pollutants, hazardous to the environment with impact on human health, animal health, etc (Baby et al., 2008). Cement dust may cause carcinogenesis, decreased antioxidant capacity and causes acute respiratory symptoms and acute ventilatory effects (Aydin et al., 2010; Zeleke et al., 2010).

Kashmir valley, a world famous health resort once known for the clean and fresh environment, is also under the severe threat of atmospheric pollution. Major sources of air pollution in Kashmir valley are cement factories, brick kilns, stone crushers and automobile exhaust. In Kashmir valley there is a great potential to produce

*Corresponding author. E-mail: balkhisana@gmail.com.

sufficient amount of cement for export and presently several factories are in operation in the areas like Khrew, Wuyan (administrative district Pulwama) and Khonmoh (administrative district Srinagar).

For the study, cement affected area of Khrew was taken into consideration. In 1979, a cement factory under the banner of Jammu and Kashmir Cements Ltd., with daily production of 600 tons which has risen to 1200 tons/year, was set up at Khrew. The factory releases an enormous amount of cement dust into the atmosphere apparently affecting the flora and fauna. Cement dust from the cement plant forms a thin deposition layer over the adjacent areas.

The adverse effects of cement pollution are well demonstrated in Khrew which has been experiencing such effects for the last three decades. The area is a live image of environmental degradation. A visit to the place is enough for one, of course without any pre-conceived notions and prejudices, to have a firsthand knowledge of the disastrous and continuous exposure to the cement pollution.

The increasing number of cement factories in Kashmir because of government promotion and local demand, is foreseen as blooming and major industry which is mainly operational near Khrew (Pulwama) and the main source for destroying world famous *Crocus sativus* (Saffron) and decreasing the health standard and thus pose threat to the flora (Jan and Bhat, 2008) and fauna (Tak and Bhat, 2009) of the region.

The present investigation has attempted to generate information on the apparent impacts of cement pollution on the health of local inhabitants with relation to air quality parameters using questionnaires, personal interviews to local habitants and workers, only non smokers were considered for study and air quality assessment was performed by using high volume air sampler enviroteck, for particulate matter cup vial method and filter paper method was used while for NO_2, Jacob and Hochheiser (1958) modified method was used and for SO_2 modified West and Gaeke (1956) method was used. The comparative study was conducted at cement polluted area of Khrew and non polluted area of Burzahama, Jammu and Kashmir, India.

MATERIALS AND METHODS

Study area

Site I

Site I was located at a distance of about 2 km from the cement factory (JK cements Ltd.) in southern direction, with dense human population. The area is covered with dwarf herbs and grasses with some scattered shrubs. Khrew is about 20 km from the main Srinagar city. Cement pollution in this area is apparent. The geographical co-ordinate of the site is 34°04´30´´ N 74°58´ 10´´ E. It lies at an altitude of 1649 m above mean sea level. This site was selected to study the impact of cement pollution on human population as the site was just two kilometers away from the factory (Figure 1).

Site II

Site II was taken as control site at Burzahama. This site is about 18 to 20 km away from the main Srinagar towards the northern side at geographical co-ordinates 34° 03´14.00´´N 075° 00´ 03.0´´E and lies at an altitude of 1632 m above mean sea level. The area remains under paddy cultivation with scattered horticultural orchards and it apparently do not receive any cement dust from the factory or any other kind of pollution so it was taken as control site. It is nearly 40 km away from cement effected area and is of archeological importance (Figure 1).

Air analysis

Ambient air quality was monitored from March to December during 2011 at Khrew near JK Cements Ltd. in Kashmir valley for priority parameters (total suspended particulate matter (TSPM), respirable suspended particulate matter (PM_{10}), non-respirable suspended particulate matter (NRSPM) and nitrogen dioxide and sulphur dioxide). In selection of sampling points, priority was given to populated areas. Two sampling points were considered for one site.

Air quality parameters such as TSP, PM_{10}, NRSPM, SO_2 and NO_2 were monitored by using high volume respirable dust sampler (Enviro-tech Instrument APM-460NL). The sampling instrument was set up 3 m above ground and hourly values for all pollutants were measured at each site. The particulate matter (PM_{10}) collected on fiber-glass filter was determined by weighing the filter before and after exposure to ambient air. Non- Respirable particles (NRSPM) were determined by dust cup vial method. TSPM was determined from the sum of PM_{10} and particles larger than PM_{10}. The mass of PM larger than PM_{10} was determined from the initial and final weight of the dust cup vial. The collected samples (fiber glass filter) were properly stored and placed in vacuum desiccators and transported to the laboratory for analysis. The samples of nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) were collected in glass impingers using sodium arsenate and sodium tetrachloro-mercurate absorption solutions, respectively. NO_2 in the samples was determined using Jacob and Hochheiser (1958) modified method, while SO_2 was determined using the modified West and Gaeke (1956) method. Samples were kept in a refrigerator until analysis to minimize volatilization.

Assessment of human health

In order to study the health hazards of cement factory on human health, the section of the population considered most suitable for study were the people residing in 2-3 km radius of the cement emission zone. All the randomly selected persons in 2-3 km vicinity of the emission zone were given a questionnaire, about 2000 subjects were taken into consideration for study, among them 1000 were male usually working as casual laborers or farmers and 1000 were females belonging to middle class families and majority of them answered frequently. Questionnaires were based on analysis of various standard organizations such as Department of Health And Ageing and Health Council (2002), WHO (1999), etc and according to the literature (Maureen et al., 1860; Lesliam et al., 2005; Winston et al., 2005; Sengupta, 2006; UNEP, 2008). In total, 10% of the population of the area was considered for study and administered questionnaires during every sampling month.

ROS and NO levels in serum of subjects were also quantified. NO is produced by various cells such as platelets, neutrophiles, macrophages, fibroblasts, in response to a number of pathological processes such as septic shock, inflammation, etc (Moncada et al.,1991; Nussler and Billiar,1993; Langrehr et al., 1992; Eizirik and

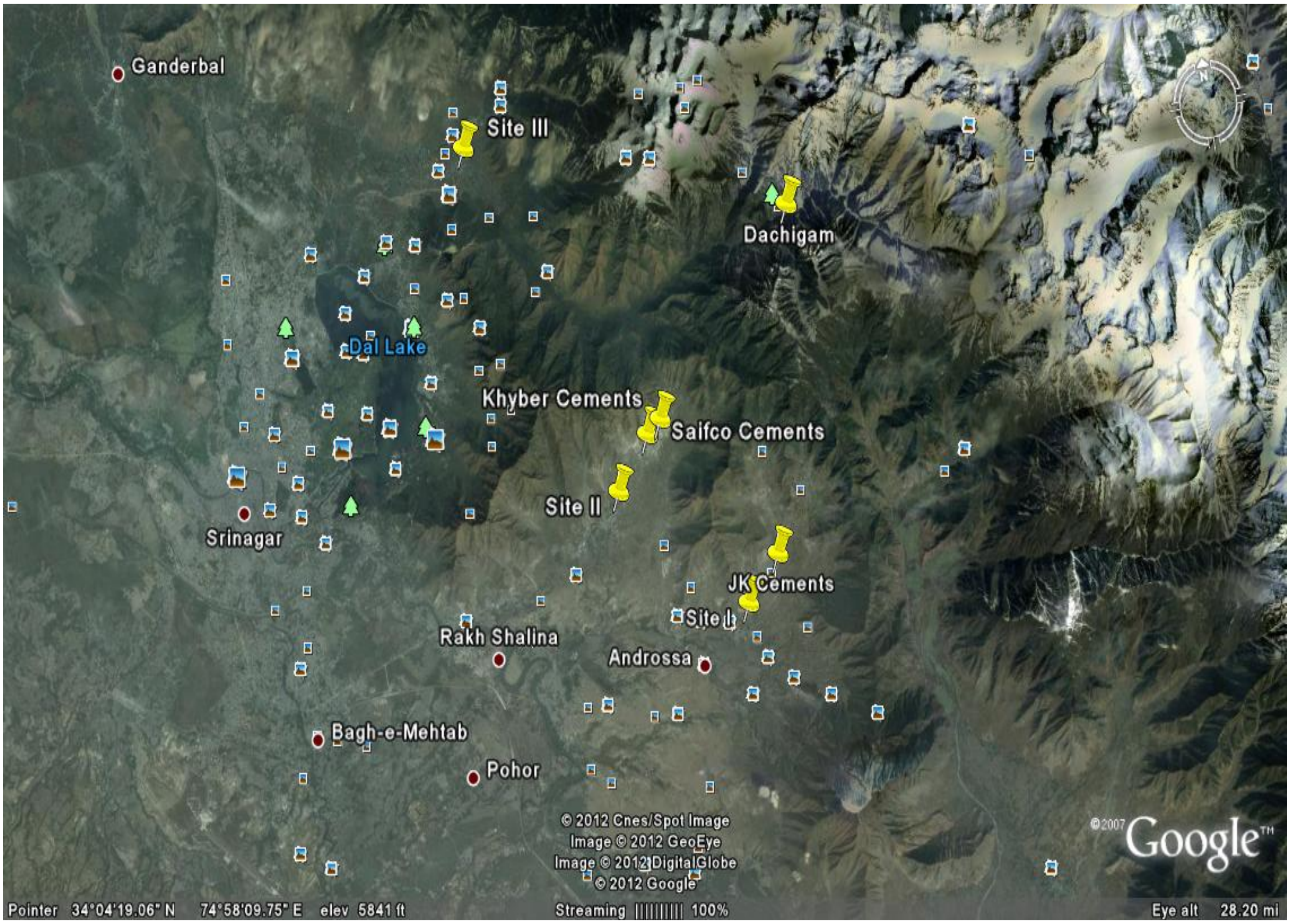

Figure 1. Study area map.

Leijerstam, 1994; Moncada, 1992; Nathan, 1992). NO is converted into nitrite ($NO_2^{-)}$ and nitrate (NO_3^-). Excessive production of ROS has been reported to have an association with wide variety of clinical disorders associated with stress. For this purpose, twenty four blood samples of subjects residing permanently within 2-3 km radius of the cement emission zone were collected. While same number of control samples were taken from subjects living in area taken as control site. All these blood samples along with subject history were provided by health centers of respective area. Among affected individuals, 11 were male and 13 females belonging to three different age groups. While as among control samples 10 were males and 14 females, belonging to similar age groups as in affected group. Total NO production was calculated as sum of NO_2^- and NO_3^- as per Griess and Ber (1879) assay. The Griess Reagent System is based on the chemical reaction, which uses sulfanilamide and *N*-1-napthylethylenediamine dihydrochloride (NED) under acidic (phosphoric acid) conditions. A nitrite standard reference curve of sodium nitrite solutions with concentrations between 1-100 µM was prepared for each assay for accurate quantitation of NO_2^- levels in experimental samples. While ROS estimation of above serum samples was carried out by spectrophotometric assay of reactive oxygen species (Hayashi et al., 2007). Standard reference curve of hydrogen peroxide was with concentrations between 50-500 mg/l.

Meterological parameters

The wind speed in the area is usually found to be calm and direction of wind was found mostly in the south-east side. Air temperature, air humidity, wind speed, wind direction and light intensity were studied at the study site. For observing the air temperature, Celsius air thermometer was used while for measuring wind speed, Beaufort scale of winds was used, and the data for direction of winds and air humidity was collected from meteorological department for sampling days. Light intensity at various sites was measured by using Lux-meter.

Statistical analysis

Two statistical parameters were used in the study which are mean and standard deviation.

RESULTS

Questionnaire studies indicates that among residents, 21 types of ailments were (Table 5) recorded which included:

allergic reactions that interfere with breathing, chronic bronchitis, asthma, emphysema, lung cancer, pneumonia, tuberculosis, shortness of breath, cough, wheezing, seizures, chest pain, irregular heartbeat, swelling in your legs and feet (not caused by walking), high B.P, eye irritation, skin allergies, anxiety, fatigue, heart burn/indigestion not related to eating and neck and back disorders. 99% of the sampled people residing in Khrew complained of allergies that interfered with breathing. High blood pressure and maximum cases of chest pain were also found at Khrew.

Irregular heart beating in the residents of the cement affected area was 51%. 96% were found to be suffering from cough in the affected area. Chest pains were complained by 49% which was high among residents. Residents in cement affected areas were suffering from asthma (49%), 97% were suffering from eye irritation in the area. Swelling in legs and feet (not caused by walking) was 43% in Khrew area while 19% were suffering from tuberculosis in. The residents were also suffering from pneumonia. The prevalence of other various diseases was also found to be high.

Nitric oxide and ROS estimation

We measured NO levels and ROS among 21 effected individuals and 21 non effected individuals. High concentration of nitrite or nitrate was observed in the subjects living in vicinity of cement pollution affected area ($P < 0.01$) when compared with subjects from control site (Figures 2 and 3). Variations according to age or gender were statistically not significant, suggesting that the differences observed between groups in our study were unrelated to age or gender. The mean NO level among effected individuals, 51.349 ± 15 µM, mean ± S.D., was significantly higher than that among non effected individuals, 40.765 ± 11 µM, mean ±S.D; $P< 0.0001$. Similarly, mean ROS level among effected individuals, 198.2 ± 60.3 units (1 unit corresponds to 1mg/l H_2O_2, mean ±S.D. was significantly higher than that among non effected individuals, 98.9 ± 21 units, mean ± S.D. ($P< 0.0001$).

DISCUSSION

The fact that air pollution is hazardous to human health is well known. WHO estimates that worldwide, at least two million people every year die prematurely due to health effects caused by lack of clean air. Air is the basic necessity of human life but the quality of air is deteriorating continuously and it is being constantly polluted from different sources. One of the major sources of air pollution are automobiles and industries, as per estimates vehicular pollution is the primary cause of air pollution in urban areas (60%), followed by industries (20-30%) in India (Sivasamy and Srinivasan,1997). Number of industries in India is increasing with time so is increase in air pollution. Cement industry is one of the most important sources of pollution. The discharge of cement factories generally consist of particulate matter, sulphur dioxide and nitrogen oxides producing continuous visible clouds which ultimately settle on the surroundings as a result the whole ecosystem around the cement factory is subjected to extraordinary stress and neglect. Huge clouds of cement dust have been seen from generations in the area right from the establishment of these factories. This dust has been settling in the area around the cement factory to a considerable distance.

During the present investigation of various components of air samplings carried out during, March 2011 and December 2011 at the study site the concentrations of all the components, remained fairly higher than the prescribed standards for residential areas as prescribed by NAAQS (Table 4a). The average estimations of SPM pollution indicated 1208.78 µg/m^3 at site with maximum SPM in the month of December (1595 µg/m^3) at site.

RSPM

During the analysis, it was recorded that the average level of RSPM was 664.98 µg/m^3. When monthly values were compared the result indicates that the highest value of RSPM of 880 µg/m^3 was seen in the month of December as shown in Table 1.

NRSPM

The results indicated that the average NRSPM value was 543.85 µg/m^3 at site. Monthly maximum and minimum values of NRSPM were 833 µg/m^3 for the month of July and 309 µg/m^3 for the month of May as shown in Table 1.

Gaseous pollutants

Sulphur dioxide values also vary, the average value of 115.82 µg/m^3 was found at the site. Monthly maximum and minimum values of SO_2 for site were 129.34 µg/m^3 for the month of December and 101.1 µg/m^3 for the month of March (Table 2). Prevalence of relatively higher levels of SO_2 during winter months can be attributed to the burning of more coal (fuel) for the manufacturing of cement in the kilns of factory and also by the burning of more coal by the employees residing in nearby quarters in cold weather conditions. Lower levels of SO_2 values during summer can be attributed to the prevalence of high wind currents to which dispersion of the pollutants takes place, resulting in lower $S0_2$ levels. Similar observations were made by Reddy and Ruj (2003) while working on the ambient air quality status in an industrial area.

Nitrogen oxide (NO_x) is emitted from the combustion of

Table 1. Monthly, mean and S.D values of RSPM, NRSPM and SPM values (µg/m^3).

Month	RSPM (µg/m^3)		NRSPM (µg/m^3)		SPM (µg/m^3) (RSPM+ NRSPM)	
	Site I	Site II	Site 1	Site II	Site I	Site II
March	595.24	97	476.19	71	1071	168
April	562.5	73	416.67	78	979.17	151
May	619.05	91	309.52	77	928.57	168
June	619.05	89	476.19	93	1095.24	182
July	666.67	96	833.33	97	1500	193
August	777.78	78	555.56	72	1333.34	150
September	595.24	91	476.19	73	1071.43	164
October	583.33	99	625	91	1208.33	190
November	750	83	555.56	79	1305.56	162
December	880.95	81	714.29	75	1595.24	156
Mean	664.98	87.8	543.85	80.6	1208.78	168.4
SD	104.19	8.715	150.74	9.47	221.36	15.32

Table 2. Monthly, mean and S.D values of SO_2 µg/m^3 at different sites.

Month	Site I	Site II
March	101.1	21.44
April	103.12	23.6
May	117.88	26.9
June	121.4	28.2
July	118.2	22.64
August	114.16	31.12
September	111.11	30.64
October	128.25	33.44
November	113.64	31.23
December	129.34	32.12
Mean	115.82	28.13
SD	9.34	4.29

Table 3. Monthly, mean and S.D values of NO_2 µg/m^3 at different sites.

Month	Site I	Site II
March	97.56	26
April	101.61	22
May	103.16	13
June	121.95	21
July	99.11	24
August	131.64	17
September	119.45	13.65
October	123.43	19
November	131.62	21
December	141.44	18
MEAN	117.09	19.46
SD	15.71	4.19

fossil fuels and also from the oxidation of NO. The highest average value of 117.09 µg/m^3 was found at the site. The S.D value of NO_2 was 15.71. Monthly maximum and minimum values of NO_2 for site was 141.44 µg/m^3 for the month of December and 97.56 µg/m^3 for the month of March (Table 3). Therefore, highest value for NO_2 was found in winter, similar observations were made by Anglauf et al. (1986).

The month wise variations in the estimations of SO_2, NO_2, SPM, RSPM, NRSPM are in general attributable to variations in wind speed and wind direction as this remained 2 km and calm, respectively, during most of sampling months so pollutants do not disperse too much and rest of the months also appeared to be well related to the variations in meteorological data of wind direction and wind speed.

Human health

The aerodynamic diameter of cement particles makes it a potential health hazard as these are respirable in size and reaches internal organs particularly lungs leading to occupational lung diseases. This size distribution would make the trachea-bronchial respiratory zone, the primary target of cement deposition. The main route of entry of cement dust particles in the body is the respiratory tract and/or the gastrointestinal tract by inhalation or swallowing, respectively (Green, 1970). Both routes, especially the respiratory tract are exposed to numerous potentially harmful substances in the cement mill environment. Besides cement dust, various gaseous pollutants are also contributed by cement factories which cause pollution and ultimately affect human health.

Table 4a. National ambient air quality standards (NAAQS) CPCB.

Sensitive area	Time weighted average	Sensitive area (μg/m^3)	Industrial area (μg/m^3)	Residential, rural and other areas (μg/m^3)	Method of measurement
Suspended particulate matter (SPM)	Annual*	70	360	140	High volume sampler
	24 h**	100	500	200	
Respirable particulate matter (RSPM)	Annual*	50	120	60	High volume sampler
	24 h**	75	15	100	
Sulphur dioxide (SO_2)	Annual*	15	80	60	West and Gaeke Method.
	24 h**	30	120	80	
Oxides of nitrogen (NO_x)	Annual*	15	80	60	Jacob and Hochheiser Modified method.
	24 h**	30	120	80	

*Annual arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval. **24 hourly/8 hourly values should be met 98% of the time in a year. However, 2% of the time, it may exceed but not on two consecutive days.

Table 4b. Meteorological parameters including temperature, humidity, wind speed, wind direction and light intensity at the study site.

Month	Temperature (°C)		Humidity (%)		Wind speed		Wind direction		Light intensity (lux, range: 2000)	
	Site I	Site II	Site I	Site II	Site I	Site II	Site I	Site II	Site I	Site II
March	15.4	19	76	54	2 m/s	Calm	NW	Calm	326	399
April	7.6	15.5	79	79	2 m/s	Calm	NE	Calm	389	421
May	25.6	24.4	46	73	2 m/s	2 m/s	S	SW	471	931
June	30.8	31.5	46	40	2 m/s	Calm	S	Calm	547	1025
July	28.3	26.8	58	79	Calm	Calm	Calm	Calm	651	957
August	32.2	32.6	65	61	Calm	4 m/s	Calm	SSE	518	901
September	31	32.2	69	58	1 m/s	Calm	SE	Calm	501	943
October	28.4	23.6	57	86	2 m/s	2 m/s	SE	SE	376	614
November	17.6	12.6	75	82	2 m/s	2 m/s	SE	SE	398	621
December	13.3	8.2	76	87	Calm	Calm	SE	Calm	314	452
Mean	23.03	22.64	64.7	69.9	2 m/s	Calm	SE	Calm	449.1	72.64

SE, South east; SSE, South-southeast; SW, South-west.

Among the residents, total of 21 diseases were found and possibly among 21, 20 may be associated with the cement dust exposure, these includes: Allergic reactions that interfere with breathing, chronic bronchitis, asthma, emphysema, lung cancer, pneumonia, tuberculosis, shortness of breath, cough, wheezing, chest pain, Irregular heartbeat, swelling in legs and feet (not caused by walking), high B.P, eye irritation, skin allergies, anxiety, fatigue, heart burn/indigestion not related to eating, neck and back disorders. Most of the residents complained about allergic reaction that interfere with the process of breathing followed by cough, wheezing, seizures, chest pain, bronchitis and even 1% cases of lung cancer were also found in the cement affected area of Khrew. The clear difference in the prevalence of diseases can be estimated from the results (Table 5) which clearly shows the impact of cement pollution. Similar observations were reported (Dockery and Pope, 1993; Al-Neaimi et al., 2001; Schwartz, 2002) in cement affected areas. According to residents, they had most times visited ENT specialist and dermatologist as well as general physician.

Some diseases which are mostly related to cement pollution such as asthma, bronchitis and emphysema patients were much more in number at Khrew which is because of the abundance of huge dust clouds in the area which is the outcome of cement factory. Cement affected area had high levels of pollution and thus low health status. The high levels of NRSPM, RSPM, SO_2, NO_x and cement dust levels in the ambient air at the cement affected areas were responsible for deterioration of health status in the study area. Therefore, there is a direct impact of ambient air quality on health status (Hart, 1970; Yhdego, 1992; Sivicommar et al., 2001; Pope and Dockery, 2006; Sabah, 2006; Adak et al., 2007).

NO and ROS quantification results showed over production of nitrogen species as well as ROS in subjects residing around cement pollution affected area. Under

Table 5. Relative occurrence of diseases with clinical features in the residents of cement polluted and control areas.

Disease	Khrew (%)	Burzahama (%)
Allergic reactions that interfere with breathing	96	3
Chronic bronchitis	57	0
Asthma	49	1
Emphysema	9	0
Lung cancer	1	0
Pneumonia	21	1
Tuberculosis	19	1
Shortness of breath	96	10
Cough	96	15
Wheezing	96	21
Seizures	7	1
Chest pain	49	11
Irregular heart beat	51	13
Swelling in legs and feet (not caused by walking)	43	0
High B.P	85	14
Eye irritation	97	12
Skin allergies	95	11
Anxiety	89	12
Fatigue	91	17
Heart burn/ indigestion not related to eating	58	11
Neck and back disorders	59	10

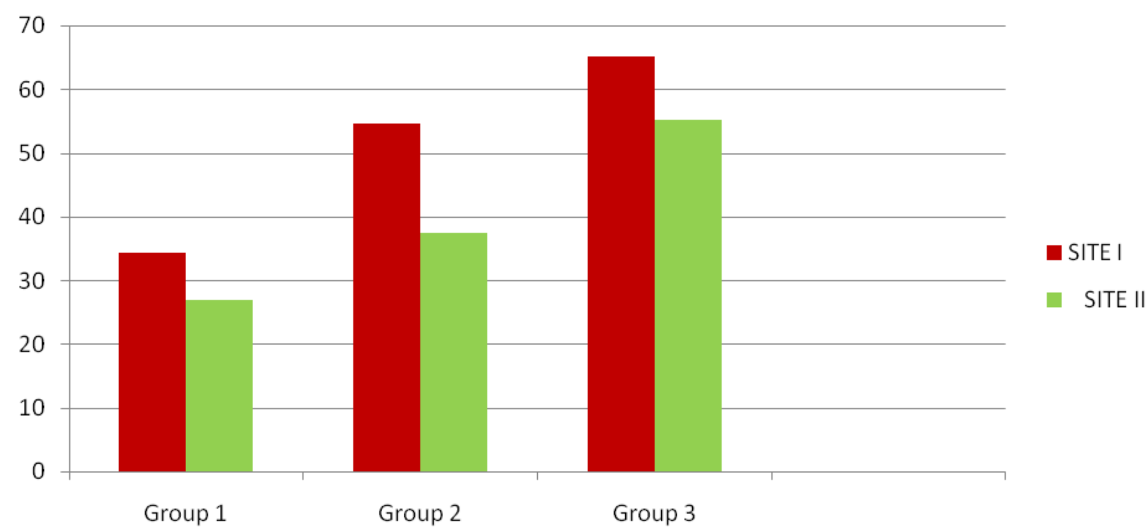

Figure 2. Serum NO levels (µm) among subjects from Site I and II. Group 1- up to age 25 years, Group 2- 25-45 years, Group 3- above 45 years.

normal conditions, NO and ROS activity is very low but it is stimulated during stress or in sustained inflammatory scenario. This is consistent with results from questionnaires and clinical data of subjects from the area, which show a high frequency of allergic and irritational complications associated with vital organs such as lungs, eyes and skin.

Conclusion

From the study, it is concluded that there was high level of gaseous and particulate pollutant load at cement polluted environment when compared with the control site and the standards prescribed by the Central Pollution Control Board of India. The present study clearly

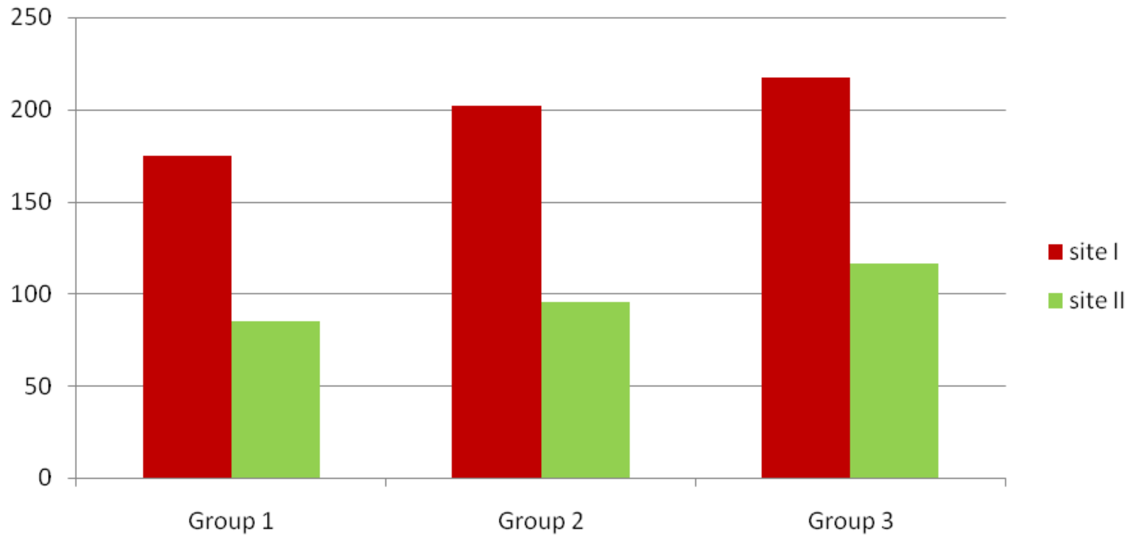

Figure 3. Serum ROS levels (units) among subjects from Sites I and II. Group 1- upt o age 25 years, Group 2- 25-45 years, Group 3- above 45 years.

revealed that cement dust is not only the major cause of environmental pollution in the study area but also a threat to health of local habitants and insightful analysis can show that the cement industries has a significant adverse impacts.

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