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ASSESSMENT OF PARTICULATE MATTER (PM 10 & PM 2.5) AND ASSOCIATED HEALTH PROBLEMS IN DIFFERENT AREAS OF CEMENT INDUSTRY, HATTAR, HARIPUR

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Abstract: The present study was conducted on cement industry at Hattar Industrial Estate, Haripur for assessment of particulate matter (PM10 & PM2.5) and its health impact on factory workers and nearby local community. Ten samples were collected from different units of cement industry and analyzed for PM10 & PM2.5.The concentrations of PM10 & 3 2.5 varied in different units of cement industry. The highest mean concentrations of PM10 &PM 2.5were found 1552 and 7867.5 ($\mu g/m^3$) in main crusher and cement mill respectively. Eighty percent of samples (both PM10 &d PM 2.5) were above the National Environmental Quality Standards (NEQS), set by Pakistan. The air pollution index (API) revealed, that majority units released high amount of particulate matter to environment, which pose significant health risk to local community. The particulate matter released by cement industry have significant impacts on human health especially the respiratory system. Therefore, it was recommended to install air pollution control devices for particulate matter, so as to minimize dust pollution inside the industry and nearby localities.

Key Words: Air quality index, cement industry, health risk assessment, haz-dust EPAM-5000, particulate matter, PM 2.5, PM10.

Introduction

The health effects caused by air pollution may include difficulty in breathing, wheezing, coughing, asthma and aggravation of existing respiratory and cardiac conditions. The human health effects of poor air quality are far reaching, but principally affect the body's respiratory system and the cardiovascular system. Individual reactions to air pollutants depend on the type of pollutants and their exposure duration, the degree of exposure, the individual's health status and genetics (WHO, 2011; Miller *et al.*, 2007).

The most common sources of air pollution include particulates, ozone, nitrogen dioxide, and sulphur dioxide. Both indoor and outdoor air pollution have caused approximately 3.3 million deaths worldwide. Children aged less than five years that live in developing countries are the most vulnerable population in terms of total deaths attributable to indoor and outdoor air pollution (Christopher *et al.*, 2004; Chen *et al.*, 2008).

The World Health Organization stated that 2.4 million people die each year from causes directly attributable to air pollution, with 1.5 million of these deaths attributable to indoor air pollution (WHO, 2008). In 2014, the New York Times reported that "India" has the highest death rate because of chronic respiratory diseases. Epidemiological studies suggest that more than 500,000 Americans die each year from cardiopulmonary disease linked to breathing fine particle air pollution (Nick, 2012; US-EPA, 2014). In 2005, European Commission calculated that air pollution reduces life expectancy by an average of almost nine months across the European Union (EEA, 2012). The reviewers also found suggestive evidence that exposure to PM 2.5 is positively associated with mortality from coronary heart diseases and exposure to SO_2 increases mortality from lung cancer (Devra, 2002).

Particulate matter comprised on toxic metals can damage respiratory system, affect lung functions and causes eyes irritation (Qian *et al.*, 2007). Inflammation of the respiratory tract causes coughing, mucus secretion, aggravation of asthma and chronic bronchitis and makes people more prone to infections of the respiratory tract. But the association of pollutants with water causes acid rains, which badly affect the ecological system (Devra, 2002, US-EPA, 2003, Roy *et al.*, 2012).

Cement industries are rapid grown sites of Pakistan because of abundant availability of raw material and infrastructure demands. Increase in population and urbanization has posed pressure on rapid growth of cement industry in Pakistan. Cement industries in Pakistan have great potential to export high quality cement to India, Afghanistan and United Arab Emirates (APCMA, 2009; Bada *et al.*, 2013).Cement industries generates heavy emissions which are potential sources of anthropogenic pollution. These heavy emissions have high concentration of toxic metals and gases which pose negative impacts on environment and human health (Wahab, 2006).Cement industry is responsible for contributing a variety of pollutants to atmosphere such as Sulfur Oxide (SOx), Nitrogen Oxide (NOx), Carbon Oxide (COx) and other pollutants such as particulate matters as well (Worrell et al., 2001; Quiros and Webb, 2005). PM10 is the size of particulates less than 10 micron, while PM2.5 is size of particulates less than 2.5 micron. Global cement industry contributes almost 5% of total Carbon Dioxide to atmosphere, which enhanced global warming (Qudais, 2011; Lei et al., 2011).

There are so many units inside cement industry such as raw mill, cement mill, silos, cooler, clinker yard, kiln, crusher and quarry, which generates a lot of dust inside industry and cause health problem to factory workers and nearby local community. The cement dust is generated during quarrying, crushing, transportation of raw materials, kiln operations, clinker cooling and milling (CPCB, 2007; Reddy, 2002).Cement dusts comprised on various types of particulate matter which are hazardous for human health. Particulate matter less than 10 micron (PM10) and less than 2.5 (PM2.5) are more hazardous for human health (Shoba and Gopal, 2012).

The current study was carried out to assess the concentration of Particulate Matter (PM10 & PM2.5) in different sites/units inside the Cement industry and to compare with NEQS along with its health impacts on workers and nearby environment.

Materials and Method

Field Visit

In order to assess the concentration of dusts (Particulate Matter), continuous field visits were carried out to identify hazardous sites inside the cement industry. Almost field visits for one month were carried out prior to measurement of particulate matter concentrations, so that areas with greater concentration of particulate matters were selected for sampling. Almost ten different sites were selected for sampling of PM 10 & PM 2.5.

Measurement of Particulate Matter

The particulate matter in cement industry was measured through Haz-dust EPAM (Environmental Particulate Air Monitor-5000), provided by Pakistan Council of Scientific and Industrial Research (PCSIR), Peshawar. EPAM-5000 is portable instrument best for measuring the indoor environmental and ambient air monitoring.

The EPAM-5000 is highly sensitive used for scattering the light to measure particle concentrations. It is a reliable instrument for measuring the concentration of particle size PM1.0, PM2.5 and PM10 & total suspended particulates ($\mu g/m^3$). It has different types of sample monitoring kit depending upon the size of particulate matter and has 47mm filter holder along with specific filters that provide accurate gravimetric samples. It used as gravimetric and real time technique which gives more accuracy in analyzing and exploring the magnitude and nature of particulates. Sampling was usually carried out for 24 hours on EPAM-5000 to get the accurate value and can be stored by instrument automatically with specific time. The EPAM-5000 was running for 24 hour in order to obtain accurate and précised reading. During 24, hours concentrations of particulate matter may vary and the instrument saved minimum and maximum reading during running time automatically. At the end, it gives the mean or average value of particulate matter, which shows precise results of particulate matter during the said time.

Statistical analysis

The statistical technique used to assess health risk was the Pollution index (PI).Pollution indexes statistical technique used to assess and calculate the Particulate Matter (PM), which correlate with PSI(Pollution standard index) to predict health risk. The "PI" for PM10 & PM 2.5 can be calculated through following formula as suggested by US-EPA (2009).

$$Ip = \frac{I_{high} - I_{low}}{C_{high} - C_{low}}(C - C_{low}) + I_{low} \dots\dots\dots \quad Eq. 1$$

Where "C_{high}" is the high break point, "C_{low}" is less break point as given in Table 4 and Table 5 for PM10 and PM2.5 respectively. "C" is the concentration ($\mu g/m^3$) in each unit, "I_{high}" and "I_{low}" is the AQI .

Results and Discussion

The particulate matter were analyzed in ten different units inside the cement industry. The detail results are given in Tables and discussed in detail as under:

PM 10 concentration

The concentrations of PM 10 in cement industry was measured through Haz-dust, running for 24 hours in each unit to get the desire results. The highest mean concentration of PM10 was found in main crusher (1552.0 μg/m³).The minerals and other necessary material for manufacturing of cement. During operational activity, main crusher generates a huge amount of dust which makes the surrounding invisible. The main crusher has dust fall bucket system (treatment plant) for controlling air pollution, but it was not in working condition, while in kiln section the treatment plant was in operation. Clinker yard 2 has second highest concentration of due to installed dust controller in Kiln unit. The rest units except raw mill and kiln have high concentrations of PM10 (above Pak-NEQS) and considered as an alarming units of health disorder and disease for factory workers and nearby localities.

PM10 (1496 μg/m³) as given in Table 1. After the completion of clinkers, the raw mill stored the clinkers in clinker yard. From the clinker yard the clinker fall from high elevation and as a result large amount of dust was emitted and enhanced the concentration of cement dusts in surrounding.

function of main crusher was to crush all sorts of

Cooler was the third in order to have high concentration (Table 1) of PM10.In cooler, the temperature of clinker becomes moderate and it can be processed for further manufacture processes. The other units such as cement mill, raw mill, clinker yard, silos, tertiary crusher and packing section have high concentration of PM10whilecomplywith Pak-NEQS).The kiln unit has less concentration (88 μg/m³) of PM10, while comply with NEQS. This low concentration was

PM 2.5 Concentration

The results showed that the concentration of PM2.5 in all the units except kiln and cooler were high from their respective permissible limits (Pak-NEQS, 2000). Cement mill showed the highest concentration of PM 2.5 (Table 2) than other units of the cement industry. The function of the cement mill was to mash all the material into powder form and mix them with other materials. During this processa very fine dust (PM 2.5) generated in surrounding area (Table 2).

Table 1. Concentration of PM10 in different areas of Dewan Cement industry

S. No	Department of the Industry	Maximum value (μg/m³)	Minimum value (μg/m³)	Mean Value (μg/m³)	NEQS (μg/m³)
1	Tertiary Crusher	1148.0	860.0	1004.0	150
2	Cooler	1329.0	1329.0	1329.0	150
3	Clinker Yard 1	688.0	688.0	688.0	150
4	Cement Mil	908.0	250.0	590.0	150
5	Silos	301.0	291.0	296.0	150
6	Packing Section	563.0	465.0	514.0	150
7	Raw Mill	137.0	86.0	125.0	150
8	Kiln	165.0	11.0	88.0	150
9	Clinker Yard 2	2143.0	849.0	1496.0	150
10	Main crusher	1702.0	1402.0	1552.0	150

Table 2. Concentration of PM 2.5 in different units of Dewan cement industry

S.No	Department of the Industry	Maximum value ($\mu g/m^3$)	Minimum value ($\mu g/m^3$)	Mean Value ($\mu g/m^3$)	NEQS,2000 ($\mu g/m^3$)
1	Tertiary Crusher	1249.0	1249.0	1249.0	150
2	Cooler	23.0	23.0	23.0	150
3	Clinker Yard 1	1320.0	98.0	709.0	150
4	Cement Mill	1030.0	705.0	7867.5	150
5	Silos	1030.0	555.0	792.5	150
6	Packing Section	755.0	250.0	502.5	150
7	Raw Mill	336.0	289.0	312.5	150
8	Kiln	80.0	21.0	50.5	150
9	Clinker Yard 2	1613.0	1551.0	1582.0	150
10	Main crusher	2140.0	1453.0	1796.0	150

The main crusher and clinker yard 2 has also high concentration of PM 2.5 i.e. 1796 and 1582 $\mu g/m^3$ respectively. The main function of these units was to crush and fall the clinkers from high elevation, which increase the PM2.5 concentration in surrounding areas. Other units such as cement mill, raw mill, tertiary crusher, silos and packing section also have high concentration of PM2.5 than the NEQS. Only the Kiln and cooler has less concentration (50.5 & 23.0$\mu g/m^3$ respectively) of PM 2.5 than the Pak-NEQS (Table 2). The low concentrations of PM 2.5 in kiln and cooler sites were due to installing dust fall buckets (small treatment plant) to control dusts.

The PM 2.5 is extremely harmful for human's health and inhaled directly, which affect the lungs function (Zeleke *et al.*, 2011).The PM 2.5has adsorbing capacity that adhere other particulates to pose further harmful impacts for the humans (Hafiz *et al.*, 2010). Once PM2.5 was inhaled, it becomes a part of lungs and permanently damages the lungs and reduces their functions (Kakooei *et al.*, 2012).

Air Quality Index

Air Quality Index (AQI) is the statistical tools used to predict and evaluate the air quality, pollution level and health concerns. As the air pollution increases, adverse health impacts also increases. If the AQI exceeds 500, than emergency will be declared and closed all the activities either industries or mining etc. (US-EPA, 2001). The Table 3 shows the air quality index, health risk and colouring the area. The air quality index zero to fifty is good for human health and indicate clean air, 50 to 100 indicate moderate air quality, 101 to 150 point toward unhealthy for target group, 151 to 200 express unhealthy for all people, 200 to 300 very unhealthy, 301 to 500 hazardous and > 500 indicate sever hazardous (Table 3).

Table 3. Pollution Standard Index (PSI) for air quality

S.N	Air Quality Index (I_{low}- I_{high})	Health Risk	Colouring areas
1	0 -50	Good	Green
2	51-100	Moderate	Yellow
3	101-150	Unhealthy for Sensitive group	Orange
4	151-200	Unhealthy	Red
5	201-300	Very unhealthy	Purple
6	301-400	Hazardous	Maroon
7	401-500	sever hazardous	--

Source: US-EPA, 2001, 2009A, 2009b, NEA, 2012.

Pollution Index for PM 10

As the concentration increases, the pollution index also increases. The highest pollution value was found at main crusher, where its concentration was found high than the other units, the lowest pollution index (81.5)and concentration (88µg/m^3) were found in kiln (Table 4).About 60% of samples sites were included in hazardous and sever hazardous, 10% included very unhealthy, 10% found in risk for sensitive group, while 20% include in moderate risk (Table 4).

Pollution index for PM 2.5

The pollution index for PM 2.5 was measured through similar formula used for PM10 (Eq. 1). The minimum, maximum and mean pollution index for PM 2.5 were 74.7, 7853 and 1658.1 respectively as given in Table 5. In PM 2.5 pollution index at least two units i.e. Cooler include in moderate risk, and kiln include in very unhealthy categories, while remaining all unites were included in hazardous and sever hazardous categories (Table 5).The cement mill and main crusher were the sites which can produce a large amount of dust, which may cause significant health risk to factory workers and local community.

Conclusion

PM2.5 and 10 concentrations were found beyond the Pakistan National Environmental Quality Standards for ambient air quality. In case of PM10 only kilns and raw mill have less concentration than the permissible limits (NEQS), while all other eight units have high concentrations of PM10 above their respective permissible limits. The Pollution Index for PM10 in most part of the cement Industry was unhealthy. According to pollution index, PM 2.5 are exhibited in hazardous and sever hazardous categories except cooler and kiln. It was, therefore, recommended to installed pollution control devices such as bag filter, electrostatic precipitators and dust fall bucket for crusher, tertiary crusher and packing, respectively.

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Table 4. Pollution Index for PM 10, Dewan cement industry

Departments	Concentration ($\mu g/m^3$)	Breaks points ($\mu g/m^3$, 24h avg.)		Pollution index
		C low	C high	
Kiln	88	0	54	81.5
Raw Mill	125	55	154	85.6
Silos	296	155	254	170.8
Packing Section	514	255	354	279.2
Cement Mil	590	355	424	538.2
Clinker Yard 1	688	425	504	630.5
Tertiary Crusher	1004	505	604	900
Cooler	1329	605	704	1225
Clinker Yard 2	1496	705	804	1392
Main crusher	1552	805	904	1448

Table 5. Pollution index for PM 2.5, Dewan cement industry

Departments	Concentration ($\mu g/m^3$)	Breaks points ($\mu g/m^3$, 24h avg.)		Pollution index
		C-low	C-high	
Cooler	23	0	15.4	74.7
Kiln	50.5	15.5	40.4	180.9
Raw Mill	312.5	40.5	65.4	636.3
Packing section	502.5	65.5	150.4	403.2
Clinker yard 1	709	150.5	250.4	754.5
Silos	792.5	250.5	350.4	838.1
Tertiary crusher	1249	350.5	450.4	1291.4
Clinker yard 2	1582	450.5	550.4	1622.3
Main Crusher	1796	550.5	650.4	2926.4
Cement mill	7867.5	650.5	750.4	7853.0

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