GEOSPATIAL APPLICATIONS FOR DETERMINATION OF PHYSICAL ENVIRONMENTAL ATTRIBUTES OF CEMENT INDUSTRIES IN SALT RANGE AREA

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ABSTRACT: The cement industry plays a fundamental role in the economic growth of a country for both developed and under developed countries. However, it is posing a great threat to the environment. This study aimed to investigate key environmental risks associated with the cement industry. The environmental assessment was conducted for eight cement industries situated in the Salt Range area, Pakistan. Ambient air monitoring was carried out according to the USEPA prescribed merthods. Stack emissions were tested for 24 hours and the annual averages for TSP, CO_x, NOx, and SO_x were estimated. The noise was also monitored across the study area. The results showed that air pollution is mainly caused by $PM_{2.5}$, PM_{10}, & TSP. Stack emissions exceeded Punjab Environmental Quality Standards (PEQS) for CO and Cl_2. Noise pollution exceeded in day and night at 12 and 20 locations respectively. The above-mentioned low environmental quality due to cement industries may intensify acute human diseases in the Salt Range area.

Key words:

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INTRODUCTION

Industrial sector play a vital role in any country's development. In Pakistan, one of the major entities of the industrial sector is the cement industry that has a significant role in the development of infrastructure. Pakistan is not only self-sufficient in the production of cement but also further exports cement to other countries such as Malaysia, Afghanistan, Sri Lanka, India, and Indonesia. Cement contributes a substantial share in national exports as being the tenth foremost exports entity. Pakistan is the eighth prime cement exporter and it has retained position among the top twenty countries that are self-sufficiently producing cement. The cement demand is anticipated to be higher in the forthcoming China-Pakistan Economic Corridor (CPEC) Projects. Production of cement has increased annually as per its demand at an average of 3498 tonnes from the year 2003 until 2017 (Hussain *et al.*, 2018).

Environmental concerns associated with cement production are, raw materials consumption and abundant usage of energy that are the main source of atmospheric emissions (Hua *et al.*, 2016; Zou *et al.*, 2018). Moreover, along with atmospheric pollution, noise pollution also affects the environment and in house of cement industries. Key atmospheric pollution emitted from cement industries are dust including total suspended particles (TSP), particulate matters ($PM_{2.5}$, PM_{10}), and gaseous pollutants, e.g., sulfur dioxide (SO_2), nitrogen oxides (NO_x), and carbon oxides (CO_x). Metals are emitted as well; including mercury (Hg), Lead (Pb), copper (Cu), cadmium (Cd), Zinc (Zn), and antimony (Sb) in a set with other metals like chlorine (Cl), hydrogen chloride (HCl), hydrogen sulfide (H_2S), and hydrogen fluoride (HF). Different parameters define air pollution category and its extent, i.e., raw material used in the process, fuels input in cement manufacturing, and the process type applied for cement production (Gupta *et al.*, 2012; Hasanbeigi *et al.*, 2012; Mbohwa & Fore, 2015). Greenhouse gases (GHGs) emission from cement production and their impact on the environment is examined in a review. The results concluded that the cement production plants are a substantial source of SO_2, carbon monoxide (CO), NO_x, and these emissions are further connected with human health and other environmental issues. Health problems such as visual impairment and adverse environmental impacts (e.g., ground-level ozone, acid rain, global warming, and water quality deterioration) are related to the emission of NO_x. sulfur dioxide cause many health problems and it is also a primary contributor to environmental issues including smog formation (ground-level ozone), acid deposition, and acid rain. Harmful health effects are also reported because of CO (Ali *et al.*, 2015).

Cement is a building block formed from a powdery material that has key ingredients of calcined lime and clay. It is a material that has properties of adhesion and cohesion and it helps to bond minerals fragments into a compact whole. Portland cement is one the most commonly used type of cement. Portland cement is a fine powder of grey/white color, comprising of a blend of hydraulic cement materials consisting of principally calcium silicates, aluminates, and luminoferrites. Silica, alumina, and iron oxide are provided to cement by the addition of clay, whereas calcined lime adds calcium oxide (Mindess *et al.,* 1981).

The raw constituents mentioned above are abundantly accessible in the Salt Range area comprising District Mianwali, Khushab, Chakwal, and Jhelum. The cement plants in the Salt Range area (total of 8,872 km^2) are causing major concerns regarding groundwater depletion, environmental degradation, and the well-being of the local inhabitants. The core aim of this study is to classify the cement plants in the research area that cause atmospheric pollution and noise pollution. This is very important to assess these physical environmental attributes in the salt Range area, as they are directly associated with potential human health threats in the surrounding communities and cement industry workers. The objectives of the current study are:

1. To predict the effect of the cement plants operations on the quality of ambient air in the adjacent areas.
2. To monitor stack emissions of the cement plants and compare them with Punjab Environmental Quality Standards.
3. To conduct the noise level monitoring in the Salt Range.

MATERIALS AND METHODS

The Study Area: The study zone falls in the Salt Range and the Trans Indus Range where the eight (08) cement plants are situated. It is comprised of Districts, Jhelum, Chakwal, Khushab, and Mianwali of Punjab Province, that covers an area of 8,872 km^2. The Motorway (M-2) crosses the Study Area and divides it into the Eastern and the Western parts. The Eastern part covers 2,258 km^2 (about 25% of the total Study Area), whereas the Western side covers 6,615 km^2 (about 75% of the Study Area). The study area has a longitudinal extent of about 222 km and a latitudinal extent of about 60 km.

The geographical location distribution of cement industries are that the five plants, i.e., Pakistan Cement (Bestway), DG Cement, Bestway Cement, Gharibwall Cement, and Dandot Cement industries are sited in the route of the East of the Motorway (M-2) in District Chakwal and Jhelum (Figure 1). The other three (03) plants, i.e., Maple Leaf Cement Plants, Flying Cement, and Pioneer Cement are located en route for the West of the Motorway (M-2) in District Khushab and Mianwali (Figure 1). Other major industries in the Study Area are Olympia Chemicals and the Sugar Mill at Jauharabad of district Khushab. The total industrial area observed from satellite imagery is about thirteen 13 km^2 (about 0.14 % of the total Study Area). There are 40,522 settlements in the study area. The total area covered by the settlements is 309 km^2 (about 3.49 % of the total study area). Some of the major settlements are Mianwali, Khushab, Daud Khel, Wan Bhachran, Quaidabad, Jauharabad, Khewra, Pind Dadan Khan, and Kala Bagh. The location of the study regions is shown in Figure 1.

Reconnaissance and Survey: Samples were collected from the eight cement plants. All the cement plants included in the study used the dry process technology for cement manufacturing. In a dry process for cement manufacturing, the raw materials are pulverized and convert this dried raw meal into flowable powder form. This raw material is placed into a long dry kiln or pre-calciner kiln or in a pre-heater. All the relevant raw material for cement manufacturing, including limestone, argilliuos clay, gypsum, and laterite/bauxite, is sufficiently available in the Salt Range area in districts of Jhelum, Chakwal, Khushab, and Mianwali. The plants are having the capacity of producing 20 million tonnes of per day cement. Samples were collected for air, and noise monitoring.

Ambient Air Data Collection: Ambient Air Quality was monitored for 24 hours, on thirty-two monitoring locations in the study area, i.e., Chhoie Mallot, Khair Pur, Badshah Pur, Daleel Pur, Tatraal, Katas Raj, Wahola, Choa Saidan Shah, Backside of APM Office, BCL Guest House, Backside of Dandot Cement (North Wall), Mid-Point of Dandot Cement and ICI Factory, Backside of Ghareebwal Cement (Channu Wala), Jotana Village, Chak Mujahid (Near Karimpur), Backside of Ghareebawal Cement (Channu wala), Mangwal Village (Flying Cement), Guest House (Pioneer Cement), Chanki Village (Pioneer Cement), Dhok Mehrwal (Downwind Direction), Mangwal (Upwind Direction), Dera Haji Raffi (District Khushab), Mahal Dhibba Near Namal College (District Mianwali), Sawans (District Mianwali), Maple Leaf Quarry Area (District Mianwali), Sorran Village Daud Khel (District Mianwali), Iskandarabad Colony (District Mianwali), Khirabad (District Mianwali), Chapri (District Mianwali), Dhandian Wala (District Mianwali), Bestway Cement Quarry Area (District Chakwal), and Dandot Cement Quarry Area (District Chakwal).

In agreement with the National Ambient Air Quality Standards-NAAQS (USEPA) the predominant pollutants were scrutinized. The monitoring methodology for ambient air quality is detailed in Table 1.

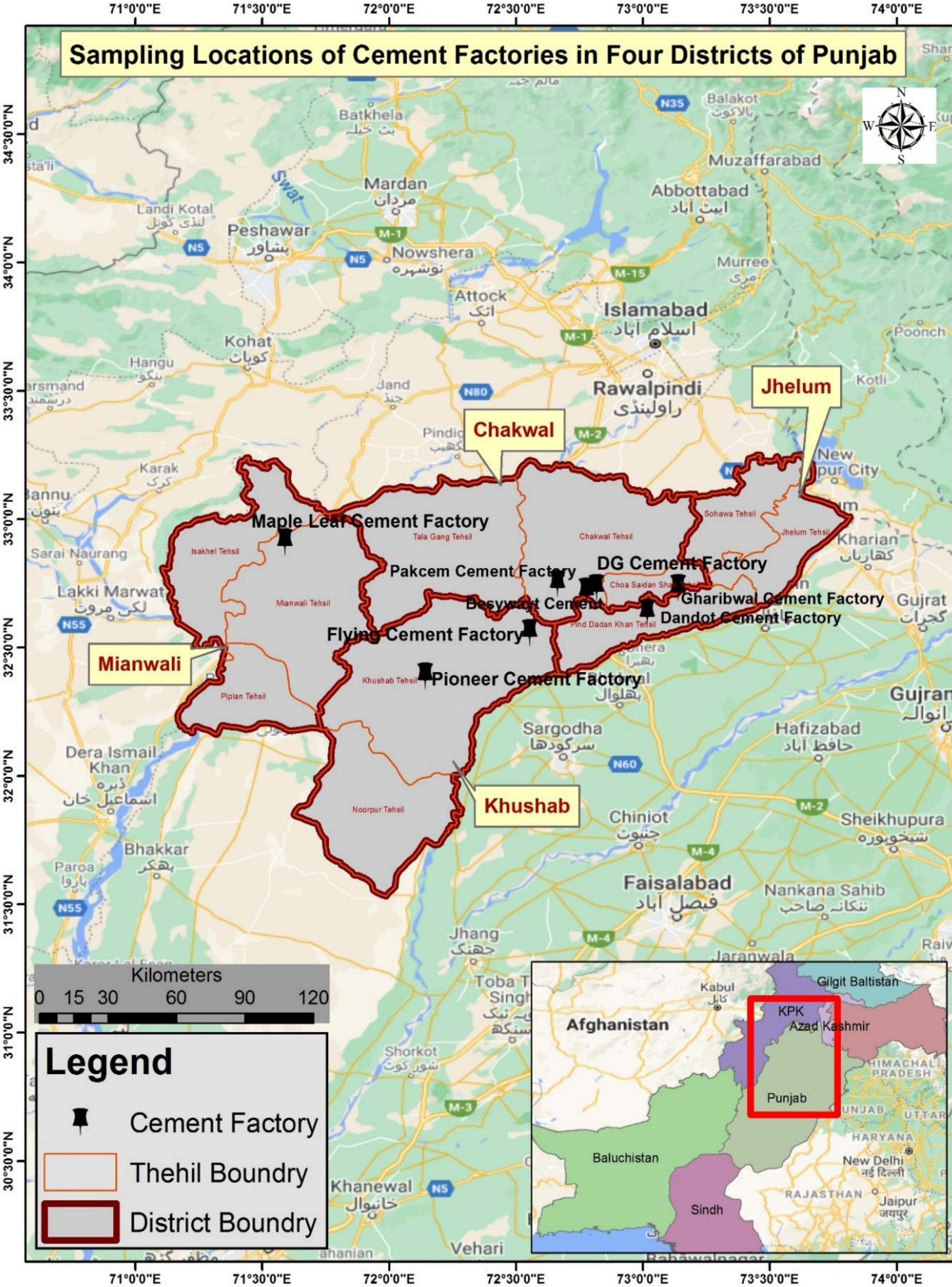

Figure 1: Location of cement plants and sampling points in four districts of Punjab Pakistan

Table 1. Ambient Air Quality Monitoring.

Sr. No.	Air Pollutant	Monitoring Technique	Method	Measurement Range	Lowest Detection Limit	Average Time Period
1.	Sulfur Dioxide (SO_2)	Pulsed Fluorescent Analyzer	US EPA Designated Method EQSA-0486-060	0– 1000ppb 0– 100ppm	1 ppb	24 hours
2.	Nitrogen Monoxide (NO)	Chemiluminescent Analyzer	US EPA Designated Method RFNA-1289-074	0– 1000ppb 0– 100ppm	1 ppb	24 hours
3.	Nitrogen Dioxide (NO_2)	Chemiluminescent Analyzer	US EPA Designated Method RFNA-1289-074	0– 1000ppb 0– 100ppm	1 ppb	24 hours
4.	Carbon Monoxide (CO)	Gas Filter Correlation CO Analyzer	US EPA Designated Method RFCA-0981-054	0-100	0.01 ppm	01 hour & 08 hours
5.	Particulate Matter ($PM_{2.5}$)	β Rays Absorption	ISO-21504-4.2007	1-1000µg/m3	2 µg/m^3	01 hour & 24 hours
6.	Particulate Matter (PM_{10})	β Rays Absorption	ISO-21504-4.2007	1-1000µg/m3	2 µg/m^3	24 hours
7.	Suspended Particulate Matter (SPM)	High Volume Sampler	40 CFR 50, Appendix B (US EPA)	--	--	--
8.	Ozone (O^3)	UV Photometric	EQOA-0880-047	0.05 -200 ppm	0.05ppm	01 hour
9.	Lead	Through the deposition of dust particles on a filter	--	--	--	--

Stack Emissions data collection: To assess the emissions from the cement plants, stack emission monitoring was conducted using Lancom III as per method CTM 34. Two stacks from each cement plant were selected, i.e., ESP Cooler and Kiln Pre-heater, as being the main emission sources of the cement manufacturing process. The monitoring was done for CO, NO_2, NO, and SO_2. PM, H_2S, Smoke, HCl, Cl_2, HF, Lead (Pb), Cadmium (Cd), Mercury (Hg), Argon (Ar), Copper (Cu), Antimony (Sb) and Zinc (Zn). The solutions for heavy metal detection were sent to the laboratory for analysis by using atomic absorption spectroscopy (AAS). The solutions of HCl, Cl_2 were submitted to the laboratory for analysis by using IC (Ion chromatograph). The USEPA approved methods were used for stack emission monitoring and the results were benchmarked against the PEQS Standards.

Noise Level Data Collection: Noise level was observed on an hourly basis for 24 hours uninterruptedly at 32 sites for day and night time. A-Class Sound level meter was operated. Class A has a range level of 28.0 dB to 135.0 dB. Three readings set from all identified particular points were recorded and the average was reported.

RESULTS AND DISCUSSION

Ambient Air Monitoring: Air monitoring trend on ground level air ecosystem indicates that most air pollutant parameters are well conforming PEQS defined guidelines except PM_{10}, $PM_{2.5}$, and TSP as shown in Table 3.

Although all monitoring locations are around the industrial premises and due to large production, there is large extent of air pollution. Yet, there is improved air quality management system for reduction of air pollution that was observed during sampling period. Better environmental management system in proper planned way reduced air pollution. This is also consistent with other studies (Chaurasia *et al.*, 2014; Chaurasia & Tiwari, 2016).

In the findings of the current study, most critical elements in the ambient air pollution are PM_{10} and $PM_{2.5}$. Average 24 hrs. concentration of $PM_{2.5}$ was found in the range of 0.83 µg/m^3 to 152.93 µg/m^3 against the PEQS value of 35 µg/m^3. The maximum concentration was recorded 152.93 µg/m^3 beyond the permissible limit at Chapri (District Mianwali). The ambient particulate matter PM_{10} was found in the range of 4.0 µg/m^3 to >1000 µg/m^3 against the PEQS value of 150 µg/m^3. The maximum concentration value >1000 µg/m^3 was obtained at Mangwal (Upwind Direction). Average 24 hrs. concentration of TSP were found in the range of 9.9 µg/m^3 to >1000 µg/m^3 against the PEQS value of 500 µg/m^3. The highest value >1000 µg/m^3 was recorded at Dhok Mehrwal (Downwind Direction) and Mangwal (Upwind Direction).This is because dust is released in various processes of manufacturing till packing process (Zeb *et al.*, 2019). The results for air pollution in this study indicated usage of sophisticated equipment and environmental management system in studied cement factories. Findings of PM_{10} and $PM_{2.5}$ in research area are damaging the environment, results are also consistent with other studies (Chaurasia *et al.*, 2014). According to Alam *et al.*, (2017), high concentration of SPM reported

Table 3. Ambient Air Parameters Compared with the PEQS

Parameter	Unit	Duration	Chhoie Mallot	Khair Pur	Badshah Pur	Daleel Pur	Tatraal	Katas Raj	Wahola	Choa Saidan Shah	Backside of APM Office	BCL Guest House	Backside of Dandot Cement (North Wall)	Mid Point of Dandot Cement and ICI Factory	Backside of Ghareebwal Cement (Chanu Wala)	Jotana Village	Chak Mujahid (Near Karimpur)	Backside of Ghareebawal Cement (Channu wala)	PEQS*
CO	**mg/m3**	**08 Hours**	1.343	1.259	1.375	1.606	1.954	1.665	1.268	1.577	1.511	1.338	1.47	1.265	1.066	1.307	1.162	1.34	5 (mg/m3) For 08 Hrs
NO_2	**µg/m3**	**24 Hours**	9.82	6.26	7.25	7.7	11.67	9.65	5.66	4.87	5.72	5.89	4.51	3.29	3.67	3.62	3.92	4	80 (µg/m3) For 24 Hrs
NO	**µg/m3**	**24 Hours**	6.08	3.82	4.7	4.9	5.96	5.34	1.26	2.96	3.8	2.04	2.24	1.31	1.3	2.22	2.74	2.94	40 (µg/m3) For 24 Hrs
SO_2	**µg/m3**	**24 Hours**	6.47	5.39	5.15	5.14	8.25	6.13	4.69	4.04	3.92	3.99	4.16	3.7	4.05	3.99	4.65	4.32	120 (µg/m3) For 24 Hrs
TSP	**µg/m3**	**24 Hours**	372.8	144.95	145.73	108.87	145.79	169.58	118.69	42.46	35.75	37.86	542.2	77.18	180.06	154.41	110.54	380.7	500 (µg/m3) For 24 Hrs
PM_{10}	**µg/m3**	**24 Hours**	152.82	79.03	74.82	86.22	102.75	109.18	73.04	20.99	17.08	15.3	381.65	18.26	74.69	40.23	34.28	124.5	150 (µg/m3) For 24 Hrs
$PM_{2.5}$	**µg/m3**	**24 Hours**	31.58	17.21	15.83	19.41	17.26	19.73	10.87	9.11	4.28	4.75	41.54	3.09	19.35	5.93	13.23	17.9	35 (µg/m3) For 24 Hrs
O_3	**µg/m3**	**24 Hours**	5.49	4.29	4.35	6.25	13.93	14.78	28.03	10.94	22.61	15.7	14.58	24.18	15.62	21.79	31.95	16.67	130 (µg/m3) For For 1 Hr
Pb	**µg/m3**	**24 Hours**	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	1 (µg/m3) For 24 Hrs
CO	**mg/m3**	**08 Hours**	1.16	1.74	1.29	2.31	2.11	2.48	1.87	1.42	1.71	1.74	1.66	1.6	1.73	1.5	1.65	1.71	5 (mg/m3)

																		For 08 Hrs
NO_2	**µg/m3**	**24 Hours**	5.68	5.2	3.46	3.93	4.55	4.07	3.88	3.13	3.75	4.04	4.74	3.75	3.49	3.53	3.69	3.5	80 (µg/m3) For 24 Hrs
NO	**µg/m3**	**24 Hours**	2.85	1.05	1.38	2.8	2.55	3.03	2.86	2.16	2.65	3.01	3.69	2.77	2.54	2.58	2.71	2.67	40 (µg/m3) For 24 Hrs
SO2	**µg/m3**	**24 Hours**	6.23	5.21	4.55	3.82	3.78	5.34	3.25	3.52	3.45	4.6	4.41	3.35	3.59	3.69	4.25	4.08	120 (µg/m3) For 24 Hrs
TSP	**µg/m3**	**24 Hours**	350.02	241.35	171	1465.68	1632.38	476.89	238.22	453.16	173.44	281.48	421.54	583.34	343.75	363.54	96.48	362.83	500 (µg/m3) For 24 Hrs
PM_{10}	**µg/m3**	**24 Hours**	176.62	106.25	83.26	712.46	1432.25	257.55	155.75	321.76	142	206.35	268.43	387.78	266.49	157.74	77.18	274.6	150 (µg/m3) For 24 Hrs
$PM_{2.5}$	**µg/m3**	**24 Hours**	24.27	19.02	15.83	43.5	42.85	57.4	43.5	89	60.67	110	126.8	109.15	152.93	75.79	37.55	55.87	35 (µg/m3) For 24 Hrs
O_3	**µg/m3**	**24 Hours**	14.02	24.59	14.6	39.95	39.04	13.61	51.4	15.2	31.05	10.16	12.4	13.93	15.11	36.38	29.04	33.53	130 (µg/m3) For For 1 Hr
Pb	**µg/m3**	**24 Hours**	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	1 (µg/m3) For 24 Hrs

***Punjab Environmental Quality Standards, 2001**

in the in-house monitoring of cement industry. It is not only damaging atmosphere but also impose threat to health of human being with asthma or other respiratory diseases. In case of low concentration alkaline cement dust, attributable to limestone, if inhaled into lungs cause no detectable harm (Abdul-Wahab *et al.*, 2018; Burchill, 2017).

AL-Taay *et al.*, (2018), also stated the details for the normality of the pollutant values is influence of: main stack filters; continuously monitored parameters in-house and out of the industry; and following environmental management system. It shows not all industrial factors are pollution sources. High level of cement byproducts such as particulate matter cause harmful impact on the human health and vegetation (Mehraj *et al.*, 2013). Transportation of raw materials, cement dispatching, lining of rotatories and vehicles are also main sources of these elements (Olowoyo *et al.*, 2015).

Stack Emissions Monitoring: Stack Emission monitoring results indicated that most emission pollutant parameters are well conforming PEQS defined guidelines except CO and Cl_2. In the following study, the average values obtained at all monitoring locations remained well within the PEQS limits except from Kiln Line #1 (Poineer Cement), and Cooler/Kiln EP (Dandot Cement), with values of 883.00 mg/Nm^3 and 1,241.00 mg/Nm^3 respectively against the standard value of 800 mg/Nm^3. Figure 2 exhibits prevailing concentrations of CO at all monitoring points.

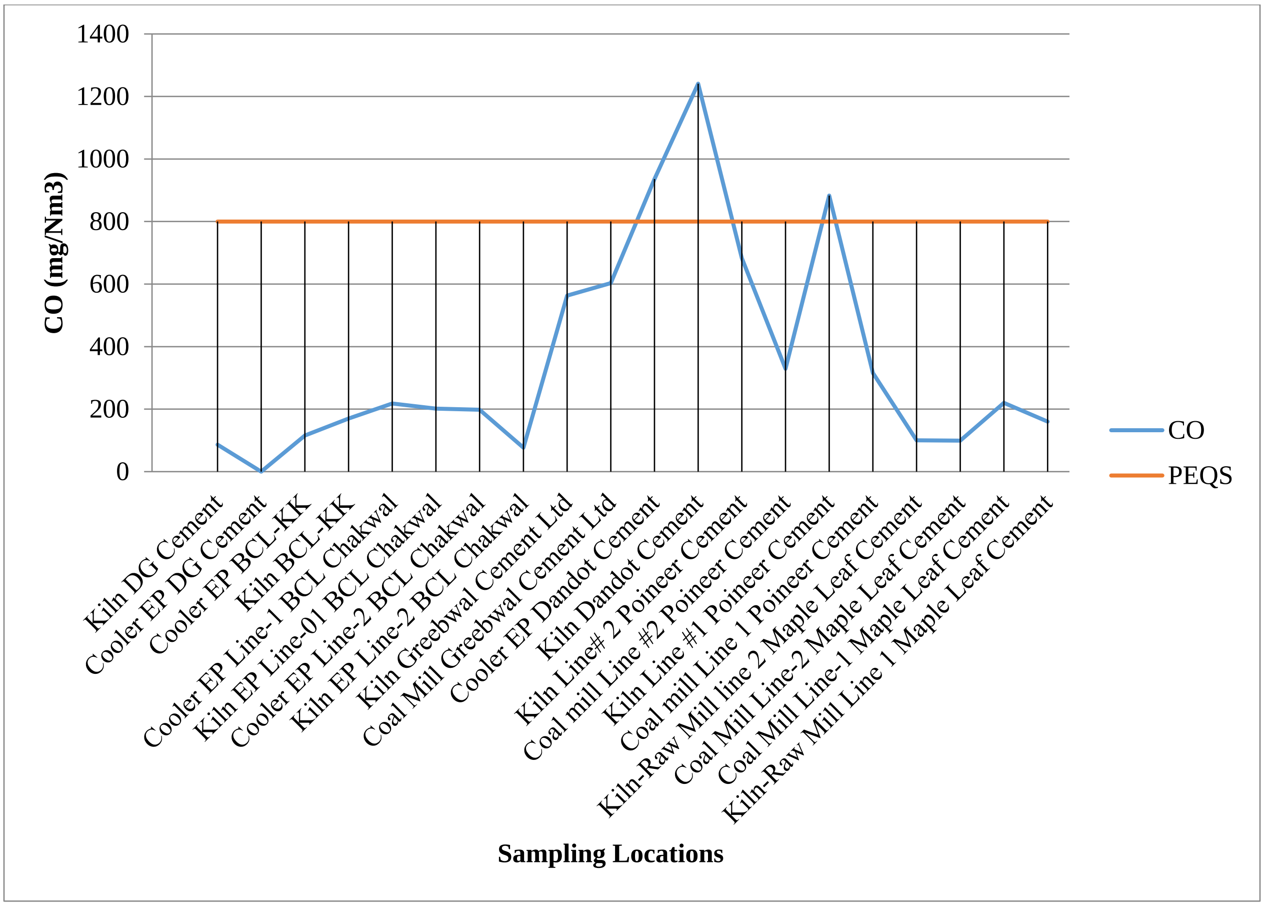

Figure 2. Stack Emission Monitoring Results for CO

Average concentrations measured for Cl_2 at all monitoring locations were found in compliance with PEQS except from Kiln (DG Cement, Chakwal), Kiln (Ghareebwal Cement, Chakwal), Coal Mill (Ghareebwal Cement, Chakwal), Cooler EP (Dandot Cement), Kiln EP (Dandot Cement), Kiln line#2 (Pioneer Cement), Kiln-Raw Mill line#2 (Maple Leaf Cement), Coal Mill Line#2 (Maple Leaf Cement), and Coal Mill Line#1 (Maple Leaf Cement) with values of 177.99 mg/Nm^3, 208.67 mg/Nm^3, 248.22 mg/Nm^3, 288.78 mg/Nm^3, 309.92 mg/Nm3, 314.87 mg/Nm^3, 344.83 mg/Nm^3, 301.73 mg/Nm3 and 371.71 mg/Nm^3 respectively against the standard value of 150 mg/Nm^3. Figure 3 reveals prevailing concentrations of Cl_2 at all emission monitoring sources performed for the study area.ibt

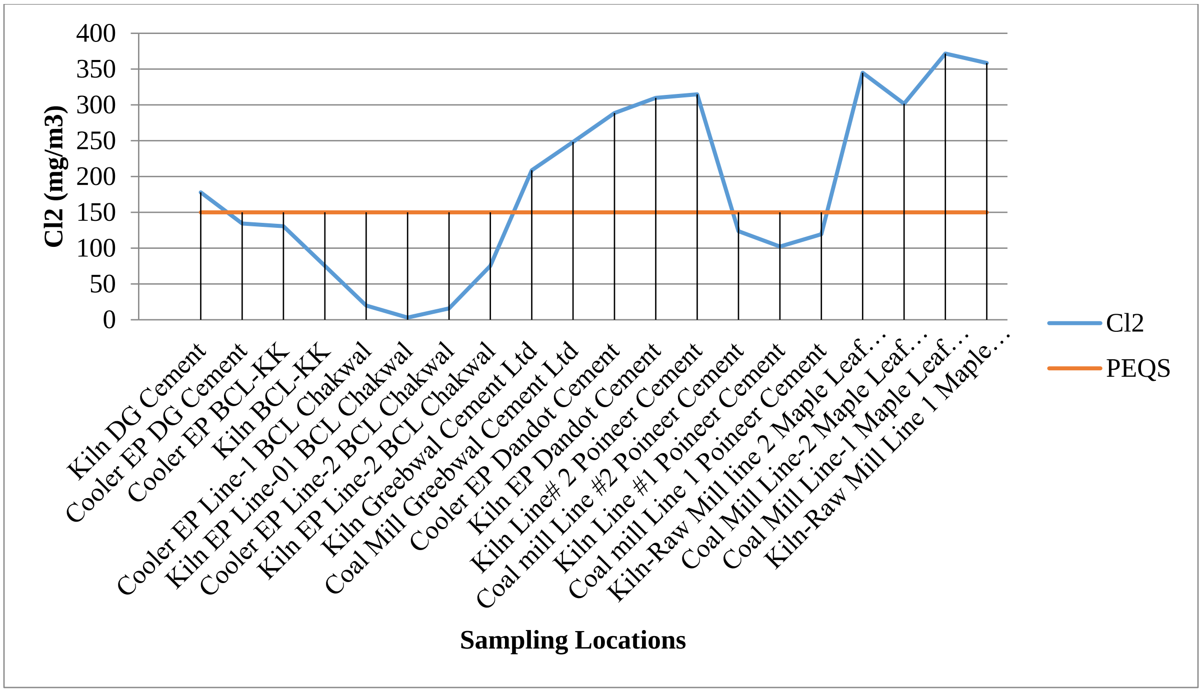

Figure 3. Stack Emission Monitoring Results for Cl_2

Holban *et al.*, (2017), conducted assessment of stack emissions including total particulates ($PM_{2.5}$, PM_{10}), oxides of nitrogen and sulfur, and carbon monoxide with continuous measurements and similar results to the current study were reported. Emissions of CO, NO_x, So_x, HCl, and HF from clinker kiln was also in compliance with standards. It is an indicator that environmental measurements can be in accordance with legislation and available control technologies can be used for reduction of emissions.

Noise Level Monitoring: Summary for the results for noise level monitoring are provided for day and night times in Figure 4 and Figure 5 respectively. Noise Level at Khair Pur, Tatraal, BCL Guest House, Backside of Dandot Cement (North Wall), Mid Point of Dandot Cement and ICI Factory, Backside of Ghareebwal Cement (Channu Wala), Jotana Village, Backside of Ghareebwal Cement (Channu Wala), Guest House (Pioneer Cement), Dhok Mehrwal (Downwind Direction), Mangwal (Upwind Direction) and Sorran Village Daud Khel (District Mianwali) showed values exceeding the PEQS limit i.e., 55 and average noise levels for day time and night time respectively. Exceeding limits of average noise level were observed for night time is observed at sampling locations of Chanki Village (Pioneer Cement), Dera Haji Raffi (District Khushab), Sawans (District Mianwali), Maple Leaf Quarry Area (District Mianwali), Khirabad (District Mianwali), Chapri (District Mianwali), Dhandian Wala (District Mianwali), Bestway Cement Quarry Area (District Chakwal), Dandot Cement Quarry Area (District Chakwal), Badshah Pur, Daleel Pur, Katas Raj, Backside of APM Office, BCL Guest House, Backside of Dandot Cement (North Wall), Mid-Point of Dandot Cement and ICI Factory, Backside of Ghareebwal Cement (Channu Wala), Jotana Village, Chak Mujahid (Near Karimpur) and Backside of Ghareebawal Cement (Channu Wala) against the standard value of 45 dB (at night time).

The noise level results of the present study conducted at surrounding of the cement factories and workers response to impacts of noise in work place are comparable to those reported in the previous studies. They also confirm prevalence of high noise levels in workplace (Mbuligwe, 2004; *Zeb et al.*, 2019). Mndeme & Mkoma (2012), conducted study in cement industry to determine levels of noise pollution and reported high levels than permissible exposure level limit. Studies on occupational and environmental noise exposure suggested an association of physiological effect like blood pressure with noise exposure. Stansfeld & Matheson (2003), also supported this by their investigation of the non-auditory effects of noise on health and results indicated the effects of environmental noise on health are strongest for cognitive performance. The results of current research are persistent with previous studies in case of exceeding limit of noise pollution at cement industrial workplace. In cement industry noise pollution is chief concern whether it is released during the production process or at packaging level (Zeb *et al.*, 2019).

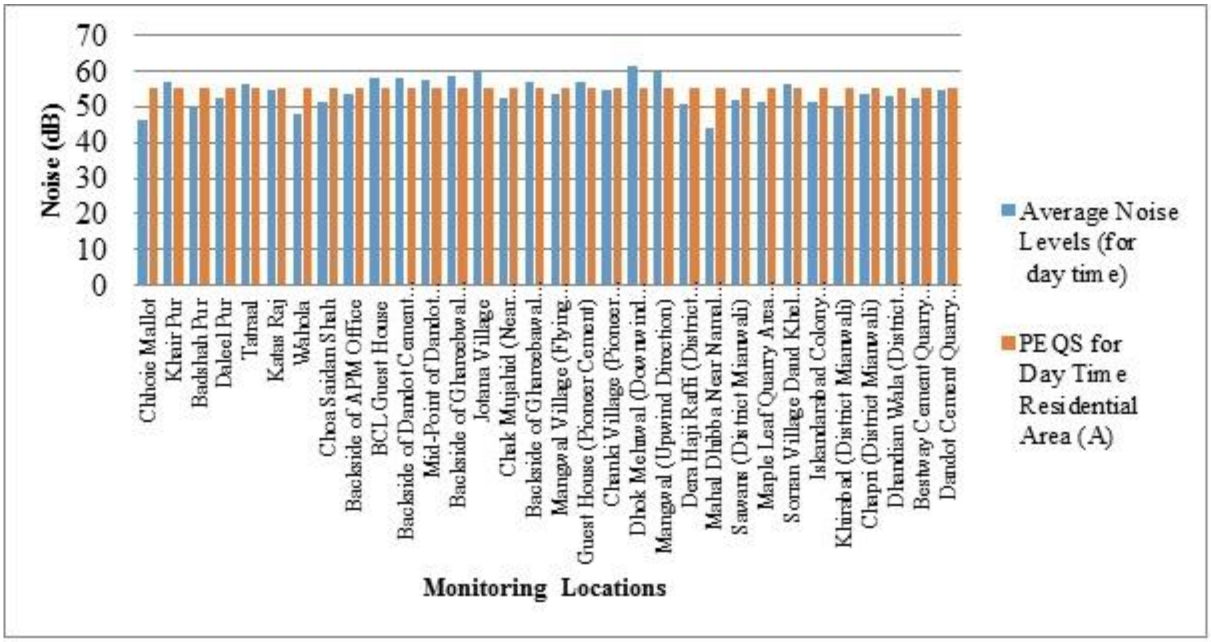

Figure 4. Noise Levels during Day Time

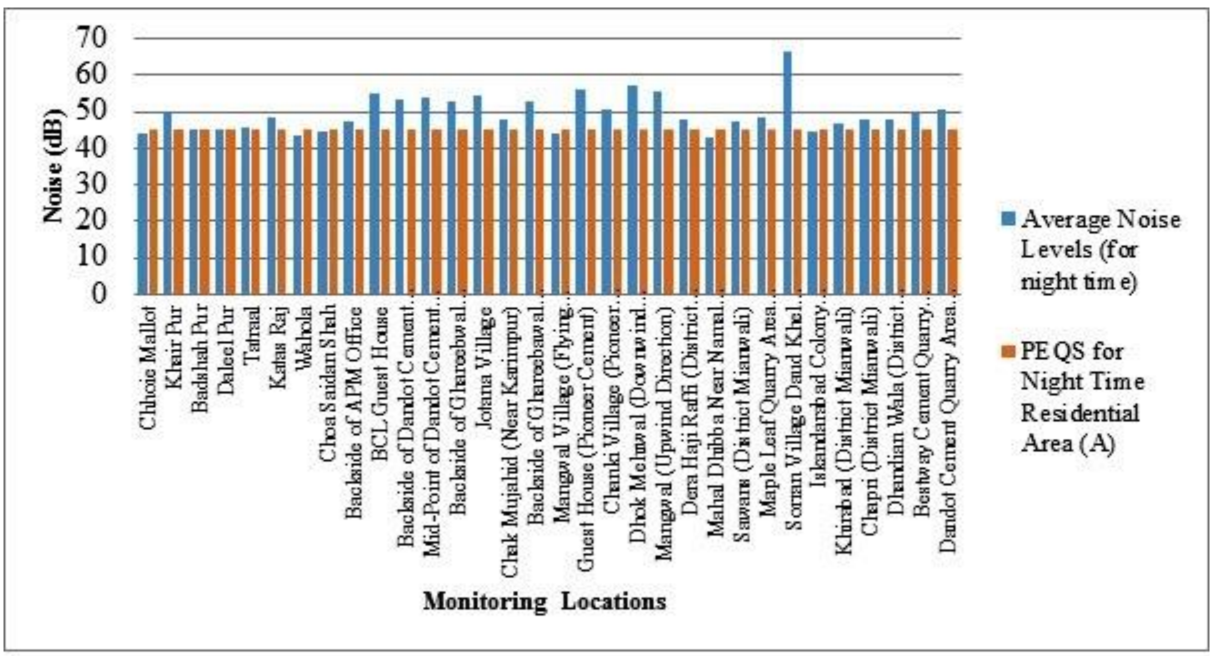

Figure 5. Noise Levels during Night Time

Conclusion: Cement industries play significant role in the economy development of Pakistan as cement industries are 5% of the total industrial sector. Nonetheless of their positive role in economic development cement industries are also triggering vulnerabilities to the environment. Particulate matters are contributing towards the deterioration of the ambient air quality that could be a great health threat to the communities living nearby these cement industries spread over the Salt Range area. Ambient air pollution (PM) and stack emissions (Cl_2 & CO) exceeding the PEQS, may also effect the workers in the vicinity of the study area. Noise pollution is another physical environmental attribute causing nuisance among the workers and the residents of the cement industries adjacent areas. These heavy noises may not only reduce the working capacity of workers but also cause diseases in nervous system, and badly affect the cardiovascular system of the workers. Nevertheless, the results of this study also prevail major atmospheric pollution can be avoided by employing good environmental control technologies, using environmental friendly raw material and good housekeeping.

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