THE CONCENTRATION OF SUSPENDED DUST IN THE QASR AHMED INDUSTRIAL AREA - MISURATA CITY, NORTHWEST LIBYA

[1]ALY Y. OKASHA, [2]KHALIL I. ABOZGIA, [3]ABDULLAH E. GOMEAI

[1]Associated Professor in Environmental Sciences, Faculty of Science, Asmarya Islamic University, & Libyan Center for Studies and Research of Environmental Science and Technology
[2]Head of Environment Department, Industrial Protection Department, Libyan Iron and Steel Company
[3]Safety Manager, Libyan Iron and Steel Company
E-mail: [1]aly.okasha2002@gmail.com, [2]khaliel4@gmail.com, [3]safety@Libyansteel.com

Abstract - The Libyan Iron and Steel (LISCO) Company is the largest industrial facilities in the Misurata city that emit gaseous and particulate effecting negatively on human health and the environmental ecosystem. This paper presents results of investigations the concentration of dust and respiratory particles in the ambient air of area outside and inside the vicinity of the Libyan Iron and Steel Company, focusing mainly on the area outside the company by 8 km from company in all directions. The results showed that the dust and respiratory particles are the biggest environmental problem in the study area, due to high concentrations of dust which found in ambient air of the study area, and a noticeable rise of respiratory particles was recorded in the area.

Keywords - Dust, PM2.5, PM10, Air pollution, Misurata, Libyan Iron and Steel Company

I. INTRODUCTION

Emissions from the combustion processes of heavy and light fuels, natural gas and burning of raw materials have negative effects on the air quality, and deterioration of surrounding environment, which may cause an imbalance in environmental ecosystems. Many researches indicate that the air pollutants are the one of most important causes of many respiratory diseases, cancer and allergies and about of 3% of deaths in the United States caused by air pollution [1].

The Libyan Iron and Steel Company (LISCO) is one of the largest steel companies in North Africa, with liquid iron production of about 1.3 million tons per year, this company uses electrical technologies in the iron and steel production. However, industrial processes and fuel burning units produce many air pollutants, in the form of solid particles, liquid droplets or gases, ranging from 0.0002 to 500 micrometers [2]. many production processes produce these pollutants. For example, the sintering processes can emit dust about 20 kg/metric ton of produced steel, and Pelletizing processes can emit dust levels of about 15 kg/metric ton of produced steel. Moreover, the smelting furnace units can emit particulate materials (PM) ranged from less than 10 kg to 40 kg/metric ton of produced steel [3,4,5]. The retention time of the micro particles in air is depending on many factories, such as climatological conditions and physical properties of particle [6], and in suitable condition, the micro particles can remain suspended in the air for several months[2].

There are different particles production sources can produce particles with different diameter. Particles over 10 microns diameters are produced from motor vehicle, soil dust, and mechanical activities such as milling and spraying, while particles ranging in size from 1 to 10 microns appear as smoke, are produced by burning processes, soil dust, volatile salts from the sea and tire friction, and particles less than 1 microns are produced by burning or condensation [7,8]. The contribution of industrial sources is not more than 10% of the total particles found in the atmosphere. However, some of these particles may be composed of organic materials [8]. It is reported that combustion processes can produce organic pollutants such as polycyclic aromatic hydrocarbons (PAHs) that are associated with micro-molecules near industrial areas, leading to increased toxicity and cancer [9,10,11].WHO guidelines for exposure to particulate matter are adopt a concentration of 10 $\mu g/m^3$ per year, 25 $\mu g/m^3$ per 24 hours as average for PM2.5, and 20 $\mu g/m^3$ per year, 50 $\mu g/m3$ per hour as average for PM10. [12]. Moreover, precipitated dust can also have significant negative impacts on biodiversity, particularly vegetation, in areas prone to high dust accumulations [13,14]

This study aims to measure the concentrations of particulate in air inside and around the headquarters of the LISCO company, and compare the concentrations with international standards of air quality to expect health effects of these pollutants on public health and the environment.

II. MATERIALS AND METHODS

2.1. Study Site

The study was conducted on the area surrounding the LISCO company in the Qasr Ahmed industrial area in the city of Misurata, for a distance of 8 km from the LISCO perimeter at all directions. This area contains

Misurata Power Station, Brega Oil and Gas complex, MisurataCommercial Port, MisurataFree Zone, the Naseem factory for foodstuffs, and Madinapaint factory, in addition to many workshops, scrap collection yards and some foundries for smelting metals, all these activities can have a negative impact on air quality. The measurements were made at monitoring points covering all the original and secondary directions located at a distance of 100, 500, 1000, 2000, 4000, and 8000 meters from the perimeter of the LISCO of each direction (Fig. 1), in addition to (15) monitoring points distributed inside the company, and the measurements were taken for (5) replicates in each point representing the specified measurement point, two points on its right and two points on its left, and each of them is (10) meters away from the other, to ensure the best representation of the trend. In view of the security conditions in Libya, samples were taken during daylight hours only from 8am to5pm, from January to December 2020, 4 to 6 rounds in each season toparticles measurements have been made at the points shown in the map (Fig. 1), the results were collected and statistical analyzes were conducted on them.

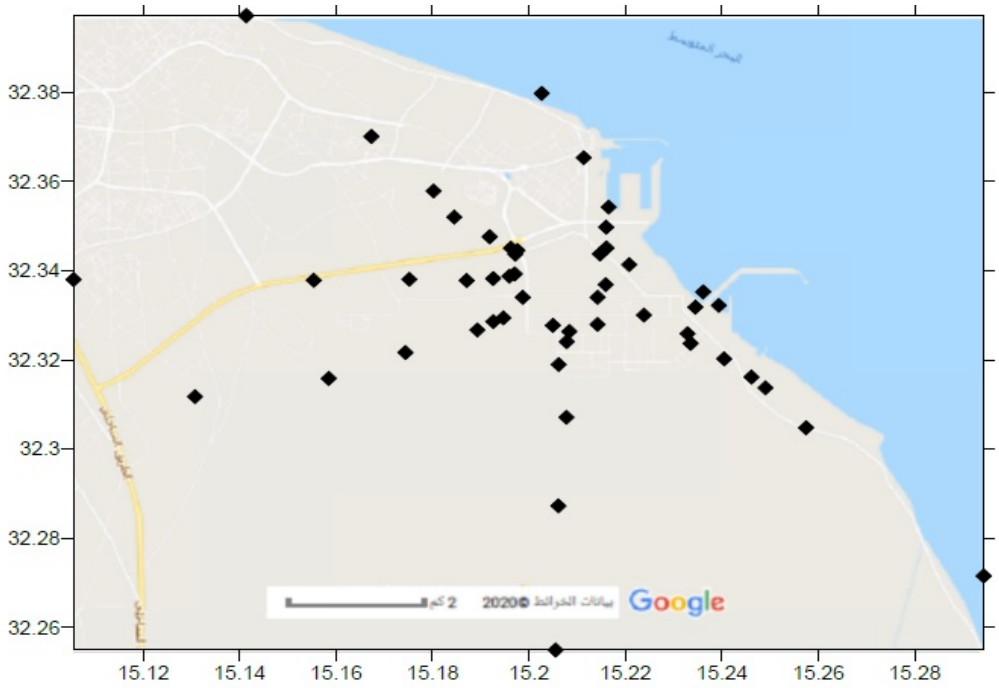


Figure (1) a map of the study area with the monitoring points.

2.2. Field Measurements

Dust concentrations were measured using a CASELLA CEL measuring device (CEL-712 Microdust Pro), AIRY Handheld Laser Particle Counter (Model P611) was used to measure the concentrations of PM10 and PM2.5, it was manually programmed to count for a fixed period of 10 seconds in each repeater and each reading was repeated 3 times, then the concentration of PM10 and PM2.5 was calculated in $\mu g/m^3$ using the method used from [15], assuming The particles are spherical in shape [16], and their density is 1.65 g/cm^3 according to [17,18].

III. RESULTS

Particulate of air pollutants are varied according to their chemical and physical properties, because of these characteristics, they are classified into groups that are varied in the degree of their impact on public health. It is classified into total dust and respiratory particles PM10 that diameter is less than 10 micrograms and fine respiratory particles PM2.5 that diameter does not exceed 2.5 micrograms. Due to the importance of each type of particulate matter, field measurements were made to calculate and predict the impact of each type separately as shown through the results next:

3.1. Dust

The results showed that there were high concentrations of dust in the study area, and dust concentrations in the region were varied widely between monitoring point and another, even between different measurements of the same monitoring point in the same season and sometimes in the same field trip. The highest concentrations of dust were 56 $\mu g/m^3$ in monitoring point which was at a distance of 1000 meters from the company site. The results of the statistical analyzes showed that there were no significant effects of distance from the factory on dust concentration, as well as the effect of the season on dust concentrations in the region ($P>0.05$). The dust concentrations in the spring were distributed almost

randomly in the region. As it seen from figure (2), there are many monitoring points of high concentrations of dust in the study area, one of them is inside the company' and the rest is distributed around the transportation route monitoring points. The highest dust concentrations were at the monitoring point, which is 2 km west of the factory and located the truck transport road, and the dust concentration was more than 130 µg/m^3. Although, there were not recording dust concentrations in some measurement trips at monitoring points, the average of the lowest dust concentrations in the study area were 6 µg/m^3.

In the summer, the dust concentrations were varied from one monitoring point to another and the dust concentration in few monitoring points were very high. For example, the highest dust concentrations were more than 600 µg/m^3 in the northwest company monitoring point, and the monitoring point, which is located 1000 meters north of the company's site. However, the dust concentrations in all other monitoring points were less than 100 µg/m^3. The figure 2 shown that there were two main dust concentration point in the area during the summer, one is north of the company's site near the commercial port, and the other is about 1,000 meters west of the site near one of the road branches of the truck transport road.

In the autumn season, the average dust concentration in the study area was 36 µg/m^3, and there were three higher dust concentration points during the autumn season (Figure 2), two of these pointswere on the sides of the truck road and near the port. The highest dust concentration was more than 180 µg/m^3 in the monitoring point, 1000 meters southwest of the company's site. this concentration was very high in comparison with international health standards. However, it is considered a natural number for the dust in Libyan open areas in Libya, due to the presence of transported dust by winds, which is common in the arid and semiarid region.

In the winter, the dust concentrations in monitoring points outside company were lower in comparison with monitoring points inside company. The average concentration of dust was 24µg/m^3 in monitoring points outside company, while these concentrations were exceeded 1000 µg/m^3 in monitoring points inside the company. The figure 2 shown that there are higher concentrations of dust were in the area within the vicinity of LISCO company and Misrata free zone up to the port and the truck transport road. The concentrations of dust in the marshes monitoring points were very low, that can be attributed to rain water in winter season which washed dust from are and precipitated in the marshes.

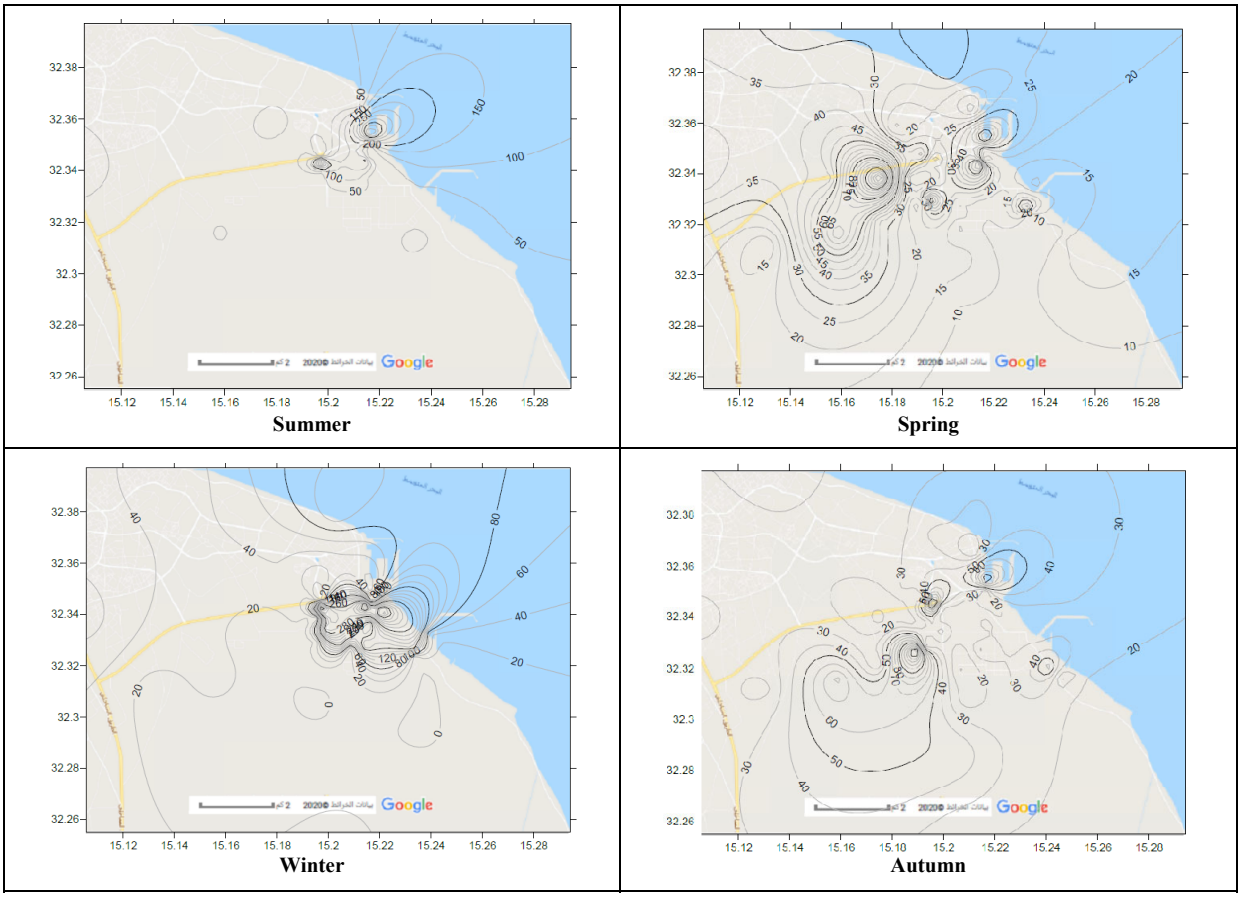


Figure (2) the contour lines of dust concentrations (µg/m^3) in the study area in the seasons.

3. 2. Respiratory particles PM10

The particles less than 10 micrometers increased withe the increase distance from the vicinity of the LISCO Company as shown in figure (3). the increases in these particles were reached higher value in the monitoring points at 4 and 8 km from the company's perimeter, at a rate of 27.2 and 24.2 µg/m^3, respectively. Although this context, which seems to be a regular increase in concentrations as move away from the LISCO company's location, the statistical analyzes indicate that these increases are not statistically significant. The statistical analyzes showed that there were no significant differences in the concentrations of PM10 in different distances as well as different seasons (P value bigger than 0.05). However, the statistical analyzes indicate the effects of direction in the concentrations of PM10 are statistically significant (P<0.01).

Although there is no significant effect of the season on the concentrations of PM10 in the study area, it is noted a small difference in the concentrations and spread of respiratory particles from one season to another. For area outside the LISCO company, the highest concentration of these particles was 165 µg/m^3 in the monitoring point 4 km northwest of the company. For the rest of monitoring points outside the LISCO company, the concentrations did not exceed 50 µg/m^3, with a general average 21.2 µg/m^3 during the spring, and in the summer, the concentrations of PM10 outside the company were limited rise with average concentrations are 21.6 µg/m^3.

the results illustrated in figure (3) shown that there was a point where the concentration of PM10 was High in summer. This point is in the north in the vicinity of the truck transport road (landfill) and within the Qasr Ahmed area. The highest concentration was at the monitoring point at 4 km away from the company, in the northwest direction near the island of Qasr Ahmed auto rotation island.

In the autumn season, although, the concentrations of PM10 decreased in the area compared to other seasons, these decreases do not mean the presence of high concentrations of these particles in many the monitoring points. For example, the highest concentration of PM10 was 119 µg/m^3 in the monitoring point located the southwest of company by 1 km. in autumn season. Moreover, respiratory particles in the area were concentrated around the road branching from the truck transport road towards the south (figure 3), That can be attributed to accumulation of road dust. It is also notice from Figure (3) that there is one main concentration point for these particles during the winter season in the area near Qasr Ahmed auto rotation island, northwest of the company's site, and in general, the average concentration of these particles at the monitoring points outside the company for winter measurements was 21.2 µg/m^3.

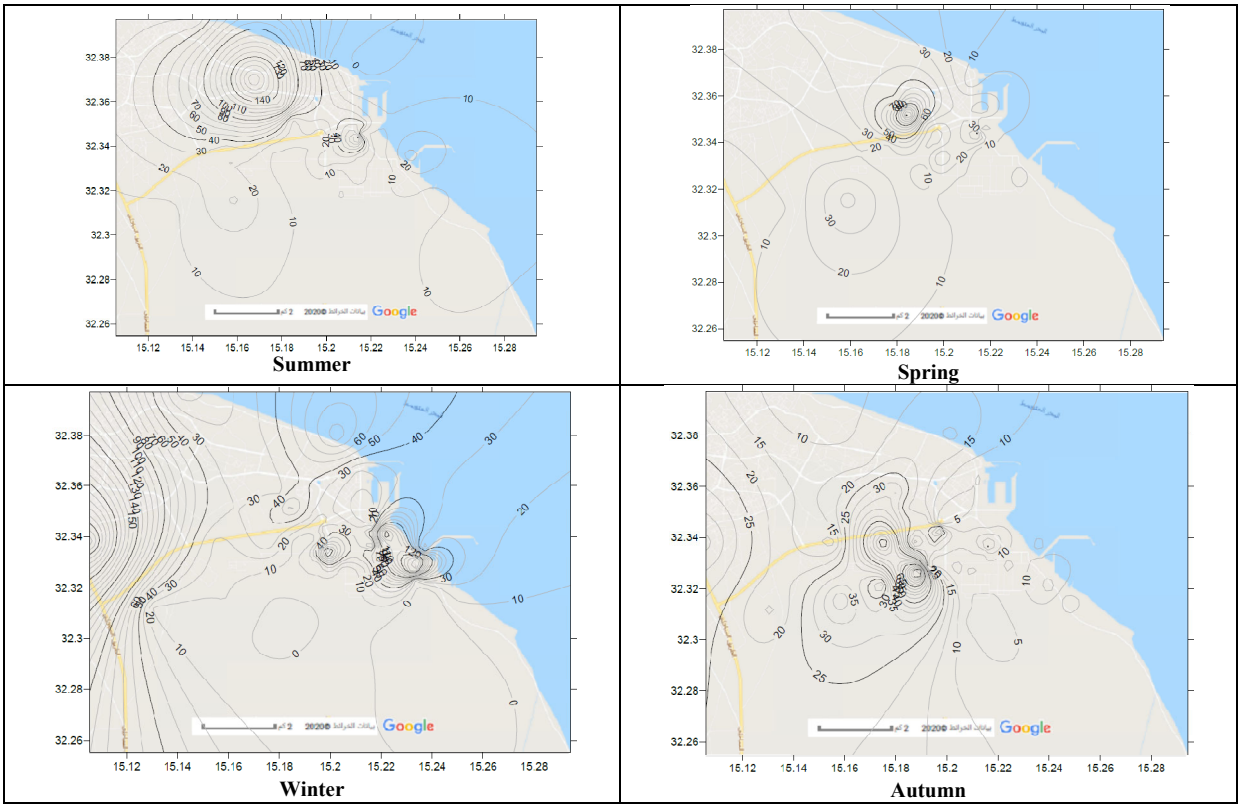


Figure (3) The contour lines of PM10 concentrations (µg/m^3) in the study area in the seasons.

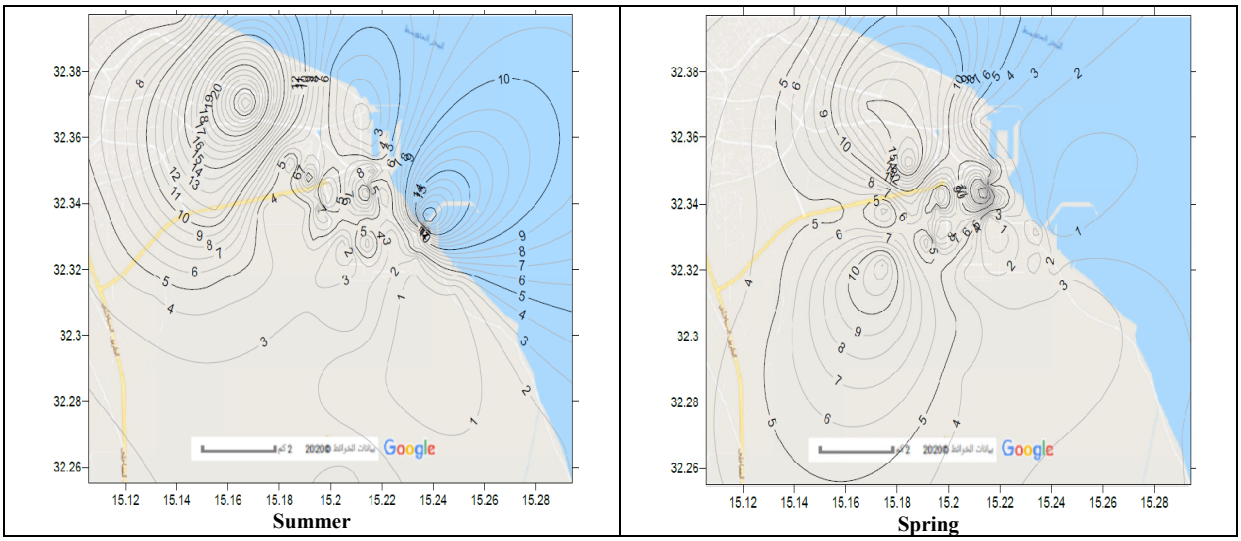
3. 3. Fine Respiratory particles PM2.5

The fine respiratory particles PM2.5 have a similar pattern to PM10 particles. The concentration of PM2.5 increased with distance from company's site. For example, the average concentration this particle at 100 meters from company was 4.3µg/m^3 and increased to 6.6 µg/m3 and 7.5 µg/m^3 at a distance of 1000 and 4000 meters respectively. However, the statistical analysis shown that there were not significant differences between distances on concentration of PM2.5 (P>0.05). Moreover, the effect of season on concentration of PM2.5 also was not significant (P>0.05). that can be attributed to the diversity and spread of the sources of these particles in the area that indicate to distribution of this particle is not does not depend much on climatic factors but on spread of the sources in area.

The concentrations of PM2.5 were rise up near crowded roads such as around the rotation island of the port and Qasr Ahmed, the landfill area and the truck maintenance workshop. The average concentration of these particles during the spring was 6 µg/m^3 and the maximum concentration of these particles was 27.9 µg/m^3, at the northern monitoring point inside the company's vicinity. These concentrations of respiratory particles in the study area were decreased to 5 µg/m^3 in summer measurements.

The concentrations of PM2.5 were rise up near crowded roads such as around the rotation island of the port and Qasr Ahmed, the landfill area and the truck maintenance workshop. The average concentration of these particles during the spring was 6 µg/m3 and the maximum concentration of these particles was 27.9 µg/m^3, at the northern monitoring point inside the company's vicinity. These concentrations of respiratory particles in the study area were decreased to 5 µg/m^3 in summer measurements. Moreover, the higher concentrations of PM2.5 were located in the northern and the northwest of company (Figure 4). The highest seasonal concentration was 28.5µg/m^3 at the monitoring point by 4 km from the company's site towards the northwest. There were many monitoring points where concentration of PM2.5 exceeded 10 µg/m^3 especially in monitoring point in northern in company site and monitoring points were located at north and northwest by 500 meter from the company and the monitoring point located by 4 km from the company towards the west.

The concentration of PM2.5 was clearly accumulated in the west and southwest of study area in the autumn season (Fig. 4), and the highest concentration of these particles was 55 µg/m^3 at the monitoring point located in the southwest side by 1000 meters from the company. Moreover, there were increases in the concentration of PM2.5 in the monitoring point located on the northwest side within the company. in the winter, it was noted that there were higher concentrations of fine respiratory particles inside the company. this concentration was 49 µg/m^3 at the monitoring point located within the company' towards the southeast. Moreover, the higher concentrations of PM2.5 were in the monitoring points by 500- and 1000-meters northwest company and was in the monitoring point by 1000 meters north of company, and the highest concentration outside the company was at the point located 8 km west of the company's site.



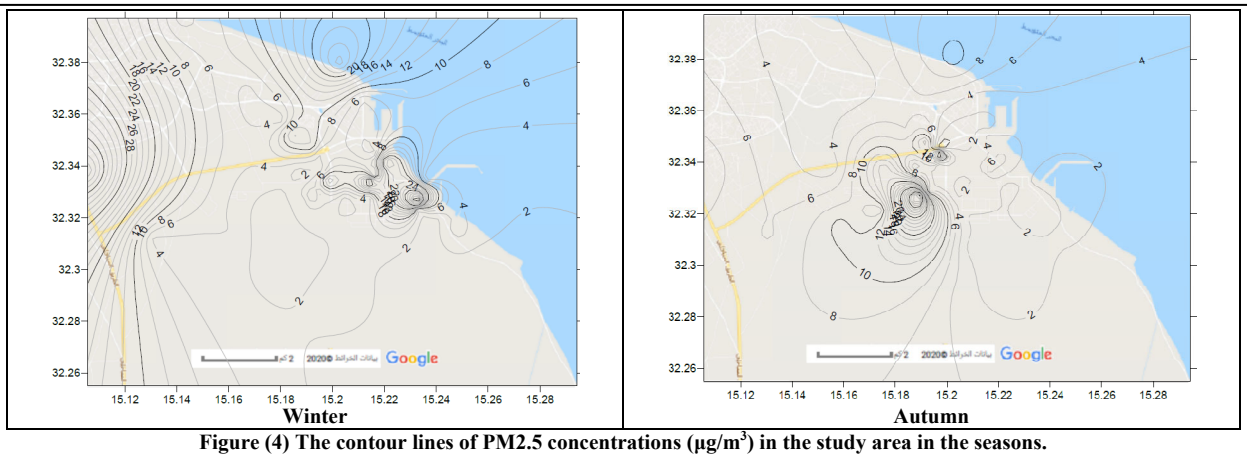


Figure (4) The contour lines of PM2.5 concentrations (µg/m^3) in the study area in the seasons.

IV. DISCUSSION

According to the standards of the World Health Organization, the maximum concentration of allowed dust for one year exposure period is 20 µg/m^3[19]. Comparison of this study results with WHO standards shown that there is a rise in dust levels in the study area with comparison to WHO standards, and that also applies to the concentrations of respiratory particles PM10, PM2.5, which are the most dangerous to public health.

There are many sources of particulates in this study area. These sources are natural such as sea spray, acacia grains, dust storms and other sources are industrially such as process of burning fossil fuels to generate Steam, power, heating, diesel engines, grinding operations, and many other industrial processes. It is difficult to predict the main cause of high amounts of dust in the ambient air of study area. However, field measurements confirm that the most quantities of dust are located next to the transport roads, and this is often due to the fact that the sides of the roads are large gathering points for dust, the passage of different vehicles on these roads, especially the trucks that emit air and waste gases from the sides, it cause to blow dust on road sides and spread it in the air again, which leads to its re-suspended in the atmosphere and an increase in its concentration almost continuously.

The presence of solid waste dumps in the area and the continuous ignition of fires in them can lead to a significant increase in the concentrations of respiratory particles in the air, especially since these particles can reach large distances, these particles is dangerous to public health. The physical properties such as size of particles is the main factor in the effectiveness and danger of particles on the living components of the environment, due to controlling their movement, transmission, spread and deposition, while the composition and chemical properties of fine particles are is the main factor in the degree of toxicity of these particles on health [20]. The particles with a diameter greater than 10 µm and the particles with a diameter of less than 0.1 µm do not pose a threat to human health, because the particles with a diameter greater than 10 µm are deposited quickly during minutes after being emitted from the source (relatively fast) and therefore are not Inhaled easily, and the particles with a diameter of less than 0.1 micrometers are inhaled and reach the lungs, but the lungs can excrete them easily [12].

The concentrations of respiratory particulates in many of monitoring points were higher than the WHO standards, which refer to 25 and 50 µg/m^3 as a daily rate that should not be exceeded for PM10 and PM2.5, respectively, While the concentration of these particles should not be exceeded 10 and 20 µg/m^3 annually for PM10 and PM2.5 respectively. The concentrations of study area are less than in many crowded cities. For example, Habeebullah[21]found that the concentrations of PM10 respiratory particles in the city of Makkah in Saudi Arabia range from 138 to 276 µg/m^3 in August and January respectively, with an annual concentration of 195.5 µg/m^3, while, the concentration of PM10 were between 78-306 µg/m^3 in Athens, Greece [22] and between 40-96 µg/m^3 in Toronto, Canada [23] and from 47 to 296 µg/m^3 in the city of salt lakes in America [24], in Beirut, capital of Lebanon, the concentrations of PM10 ranged between 55 and 118 µg/m3, and the concentrations of PM2.5 ranged between 20 and 40 µg/m^3[25], PM10 and PM2.5 concentration were 49.03 and 21.85 µg/m^3, respectively near one of the largest iron and steel complex in the southern Italian.

the concentrations of dust in study area should not be underestimate because the references indicate that low concentrations in the range of 18 µg/m^3 of particulate pollutants with a size of less than 10 microns (PM10) are associated with an increase in the number of deaths, this concentration is lower than the maximum limit of American standards, [26]. There are risks to the health of the population in cities where concentrations of less than 12.5 µg/m3 of these particles are recorded, while the health risks worsen when exposure for higher concentrations (in the range of 15 µg/m3) [27]. The WHO air quality guidelines indicated that the risk of death from heart and lung

diseases can begin at long-term exposure (chronic injuries) to concentrations of 20 μg/m^3 of particulate matter. Another study indicates the increase in human mortality rates ranged from 0.3% to 1.6% for each increase of 10 μg/m3 in the annual average of PM10 concentrations, as there is a statistical relationship between exposure to different doses of particulate concentrations and the mortality rate, these concentrations are less than concentrations in many monitoring points in study area, this means a great possibility of dangers to public health.

The most important of particles health problems are coughing and difficulty breathing, poor lung function, asthma, the emergence of acute inflammation in the bronchial tubes and disturbance of the airway. Fine particles affect the human being alone or in combination with other air pollutants, through contact with the skin and eyes and penetration into the respiratory system and cause various diseases, especially bronchitis and pneumonia that affect the small bronchi and obstruct the passage of air, making breathing difficult, in addition to Incidence of emphysema, asthma, weakness and general fatigue, eye diseases, especially lacrimal disease, and the increase in the proportion of fine suspended particles is usually accompanied by more serious health risks such as heart disease and disruption of lung function, in addition to lung cancer [8].The presence of dust in the ambient air in high concentrations, as shown in the results of this study an bring significant negative effects, not on human health only, but also on biodiversity in all its forms in the region, especially the vegetation cover, plant species that are highly affected when exposed to high concentrations of dust, as is the case in areas near to cement factories in Libya [13,14].

V. CONCLUSIONS

The concentrations of particles in the air were monitored during a year. Through the results of this study, the research team reached the following:

- Particulate pollutants such as dust and respiratory particles are the biggest environmental problem in the study area, and the high amounts of dust in the air of the area are often due to the movement of dust from the surface of the soil by the wind. The dust produced by the company's chimneys alone is hardly a danger to the environment. However, the danger is in the scattering of the accumulated dust on the ground, whether from natural sources or from company dust, such as the dust of the lime factory, grinding operations, falling from belts and suction channels.
- The field measurements confirmed that the most amounts of dust are accumulated next to the transport roads, and once different vehicles pass next to them, especially trucks that emit gases from the side of these roads that causes dust to be blown out and spread into the air again, leading to its resuspension in the air and an almost continuous increase in its concentration.
- Ignition of fires in solid waste dumps in the region leads to a significant increase in the concentrations of respiratory particles in the air, especially since these particles can reach large distances more than they reach large distances, and this matter is extremely dangerous to public health.

ACKNOWLEDGMENTS

We would like to thank the Libyan Iron and Steel Company and the Libyan Center for Environmental Science and Technology Studies and Research, for their support to the research team during field measurements.

REFERENCES

[1] USEPA, US Environmental Protection Agency. Understanding the Clean Air Act. Brief History of the Clean Air Act.2008

[2] Okasha. Y. A., Elatrash, M.S. and Elsol, M. M. Air Pollutants Emission from Iron & Steel Plant and its Dispersion Over Misurata City, North-Western Libya, Proceedings of 2nd conference on Environmental Sciences, Zliten, Libya, 401 – 413, 2015.in Arabic.

[3] Amodio, M. E. Andriani1, G. de Gennaro, A. Di Gilio, P. Ielpo, C.M. lacentino, M. Tutino. How a Steel Plant Affects Air Quality of a Nearby Urban Area: A Study on Metals and PAH Concentrations, Aerosol and Air Quality Research, 13: 497–508, 2013.

[4] Xuecheng Wu, Lingjie Zhao, Yongxin Zhang, Chenghang Zheng, Xiang Gao, Kefa Cen. Primary Air Pollutant Emissions and Future Prediction of Iron and Steel Industry in China, Aerosol and Air Quality Research, 15:1422–1432.2015.

[5] Zhiyong Li1, Yutong Wang, Yao Hu, Lan Chen, Hongtao Zhu. Emissions of NOx, PM, SO_2, and VOCs from Coal-fired Boilers Related to Coal Washing, Iron-steel Production, and Lime and Gypsum Making in Shanxi, China, Aerosol and Air Quality Research, 19: 2056–2069, 2019.

[6] Afifi F. A. Dynamics of toxins and environmental pollutants and the response of the respiratory and circulatory system to them, first edition, Dar Al-Fajr for Publishing and Press, 193-85, 2000.in Arabic.

[7] Hyoung g. R., Jongbae H., Sun-Young K. Source apportionment of PM10 and PM2.5 air pollution, and possible impacts of study characteristics in South Korea, Environmental Pollution 240: 963-972, 2018.

[8] Raczynski, A and Watson, R.T. Pollution Prevention and Abatement Handbook 1998 - Toward Cleaner Production, The World Bank Group, The International Bank for Reconstruction and Development/THE WORLD BANK, Washington D.C. 1999.

[9] Dvorská, A., Lammel, G. and Klánová, J. Use of Diagnostic Ratios for Studying Source Apportionment and Reactivity of Ambient Polycyclic Aromatic Hydrocarbons over Central Europe. Atmos. Environ. 45: 420–427, 2011.

[10] Castro-Jiménez, J., Berrojalbiz, N., Wollgast, J. and Dachs, J. Polycyclic Aromatic Hydrocarbons (PAHs) in the Mediterranean Sea: Atmospheric Occurrence, Deposition and Decoupling with Settling Fluxes in the Water Column. Environ. Pollutant, 166: 40–47, 2012.

[11] Tobiszewski, M. and Namiesnik, J. PAH Diagnostic Ratios for the Identification of Pollution Emission Sources. Environ. Pollut.162: 110–119, 2012.

[12] WHO. Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide - Global Update 2005. Geneva: World Health Organization.2005.http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf

[13] Okasha. Y. A. Effect of Al-Mergeb Portland Cement Factory on Vegetation Cover, J. of Elngah University for Natural Science. 26: 85 – 100, 2012, in Arabic.

[14] Horiz H., Okasha A. Y. and Almethnani A. M. The impact of Libda cement plant (Khoms - Libya) on the qualitative and diversity of diversity of vegetation cover in the surrounding area, JOPAS, 17 (1): 493-500, 2018.

[15] Tittarelli, A. Borgini, A. Bertoldi, M. De Saeger, E. Ruprecht, A. Stefanoni, R. Tagliabue, G. Contiero, P. and Crosignani, P. 2008. Estimation of particle mass concentration in ambient air using a particle counter, Atmospheric Environment 42: 8543–8548.

[16] Wittmaack, K., Advanced evaluation of size-differential distributions of aerosol particles. Journal of Aerosol Science 33, 1009–1025, (2002).

[17] Tuch, T., Mirme, A., Tamm, E., Heinrich, J., Heyder, J., Brand, P., Roth, C., Wichmann, H.E., Pekkanen, J., Kreyling, W.G. Comparison of two particle size spectrometers from ambient aerosol measurements in environmental epidemiology. Atmospheric Environment, 34: 139–149.2000.

[18] Weijers, E.P., Khlystov, A.Y., Kos, G.P.A., Erisman, J.W., Variability of particulate matter concentrations along roads and motorways determined by a moving measurement unit. Atmospheric Environment 38, 2993–3002,2004.

[19] WHO. Air Quality Guidelines for Europe: http://www.who.dk/InformationSources/Publications/Catalogue/20010910_6, 2010.

[20] WHO, Health effects of particulate matter Policy implications for countries in eastern Europe, Caucasus and central Asia, WHO Regional Office for Europe, UN City, Denmark (http://www.euro.who.int/pubrequest).2013

[21] Habeebullah T.M. Health Impacts of PM10 Using AirQ2.2.3 Model in Makkah, Journal of Basic & Applied Sciences, 9: 259-268, 2013.

[22] Touloumi G, Pocock SJ, Katsouyanni K, Trichopoulos D. Short-term effects of air pollution on daily mortality in Athens: a time-series analysis. Int J Epidemiol 1994; 23: 1-11, 1994.http://dx.doi.org/10.1093/ije/23.5.957,

[23] Ozkaynak, H., Xue, J., Spengler, J., Wallace, L., Pellizzari, E., & Jenkins, P. Personal exposure to airbourne particles and metals: results from the particle team study in Riverside, California. Journal of Exposure & Analytical Environmental Epidemiology, 6: 57-78, 1996.

[24] Lyon JL, Mori M, Gao R. Is there a causal association between excess mortality and exposure to PM10 air pollution? Additional analyses by location, year, season and cause of death. InhalToxicol. 7: 603-14, 1995, http://dx.doi.org/10.3109/08958379509014468

[25] Caprissia S. Environment in Lebanon: Reality and Trends - Air Quality, Chapter 4, MOE/UNDP/ECODIT, 88-123, in Arabic, 2011, https://www.undp.org/content/dam/rbas/doc/Energy%20and%20Environment/SOER_ar(1).pdf

[26] US EPA, US Environmental Protection Agency, National Emission Standards for Hazardous Air Pollutants from the Portland Cement Manufacturing Industry and Standards of Performance for Portland Cement Plants, ENVIRONMENTAL PROTECTION AGENCY, Federal Register / Vol. 75, No. 174 / Thursday, September 9, 2010 / Rules and Regulations, USA.(2010). http://www.epa.gov/air/caa/peg/understand.html

[27] Dockery D.W., Pope, C.A., Xiping, X. Spengler, J., Ware, J., Fay, Ferris, B., Speizer, F. An association between air pollution and mortality in six U.S. Cities, New England Journal of Medicine, 329 (24): 1753 – 1759, 1993.

★★★