Research Paper

A Probable Mechanism for Recurring Outbreak of Respiratory Syndrome During Autumn Season in Ahvaz City, Iran

Mohammad Reza Dayer[1*]

1. Department of Biology, Faculty of Science, Shahid Chamran University of Ahvaz, Ahvaz, Iran.

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ABSTRACT

Background: Recurring annual asthma or asthma-like outbreak in Ahvaz City, Iran, has become a serious public health problem. A toxic gas, a chemical compound, or an allergen with unknown nature and mechanism leads to severe asthma outbreaks each year. Bronchospasm, cough, dyspnea, chest tightness, and wheezing are the main symptoms of these attacks. Oxygen and anti-asthma therapy are effective treatments in outbreak management. Based on our findings, it is hypothesized that vast amounts of ammonium nitrate used in agriculture underlay high concentrations of nitrate. This substance is transported by PM_{10} and is the main cause of the respiratory outbreak.

Methods: The concentration of nitrate was determined by the ion chromatography method in dust samples during 2015-2016. Using spectroscopic methods, the effect of nitrate ions on hemoglobin oxidation and methemoglobin formation was studied.

Results: Our results indicate that the concentration of ammonium nitrate in dust collected from indoor spaces is five times higher than the levels allowed amount in airborne pollutants. Our findings also indicate that this concentration of nitrate in the bloodstream can instantly increase methemoglobin percent to 18% with symptomatic consequences.

Conclusion: The exact mechanism proposed by this study is that inhaled nitrate or nitric acid finally increases the nitrate in the circulation of affected individuals. Hemoglobin oxidation and methemoglobin formation are the subsequent events leading to methemoglobinemia with asthma-like reactions seen in Ahvaz respiratory syndrome. Restricting or even prohibiting ammonium nitrate application in agriculture seems to be an urgent measure to stop Ahvaz's recurring respiratory syndrome.

* **Corresponding Author:**
Mohammad Reza Dayer, PhD.
Address: *Department of Biology, Faculty of Science, Shahid Chamran University of Ahvaz, Ahvaz, Iran.*
Phone: *+98 (916) 6180371*
E-mail: *mrdayer@scu.ac.ir*

1. Introduction

It is well known that respiratory outbreak associated with thunderstorms seen in the southwest of Iran, i.e. Ahvaz City, Iran, is mediated by dust particulate matters of PM_{10}, $PM_{2.5}$, and PM_1 with 10, 2.5, and 1 mm diameters, respectively [1-5]. These particulate matters carry large quantities of toxic chemicals, coal, oil, heavy metals, aromatic hydrocarbons, inorganic and immunogenic compounds [6-9]. It is also documented that ultra-fine PM particles with diameters lower than 2.5 mm can go down to lower parts of the respiratory tract and even to the bloodstream, carrying toxic materials to interstitial fluids of the pulmonary tract and hamper their physiological functions [10, 11]. Different studies indicated that these particles at more than 420 mg/m^3 concentrations are hazardous and leads to respiratory tract inflammation and asthma symptoms [12-14].

Ahvaz, the capital city of Khuzestan Province, is exposed to large emissions of pollutants each day due to surrounding steel, petrol, petrochemical, textile companies, and agricultural projects. Because of its proximity to major sources of dust in the Middle East countries, i.e. Iraq, Saudi Arabia, and Kuwait, this city is experiencing major dust events each year with thousands of milligrams per cubic meter of particulate matter [15-17]. Considering their high capacity, PM particles carry large quantities of toxic pollutants on dusty days [18-21].

Unlike other seasons, the asthma outbreak in Ahvaz starts merely in autumn with the beginning of the first rain. The conditions of low temperature, high humidity, surface wind blow, lightning, and thunder with unknown mechanism interact each year to cause asthma outbreak in thousands of people who refer to hospitals for urgent care [22, 23].

Hypothetically, the severity of the outbreak depends on the concentration of the causal factor or its activation state each year. The suspected factor leading to asthma-like reactions may be a toxic compound associated with PM particles in a gas, liquid, solid form, or an allergen in aerosol form [24].

Not only young children and elderly individuals with asthma or cardiovascular disease backgrounds but also young adults without any backgrounds are affected by this outbreak [1, 22].

Ammonium nitrate (NH_4NO_3), a highly water-soluble (150 g/ 100 mL) chemical used predominantly as a fertilizer in agriculture, comprises the major source for environmental contaminants. Urban ammonium nitrate at trace amounts also may arise from the atmospheric reaction of ammonia and nitric acid emitted from industrial activities [25]. Ammonium nitrate quantitatively comprises the second compartment of PM_{10} particulates and hence acts as an essential contaminant. Because the total amount of PM_{10} reported for Ahvaz each year is about five times of $PM_{2.5}$ and PM_1, ammonium nitrate seems likely to make a serious contaminant in dusty days in this metropolis [22, 26]. Based on the Knoema database (https://knoema.com), the annual changes in ammonium nitrate production in Iran correlate with the severity of the outbreaks period.

In the late 19th century, it was shown that aerosols containing ammonium nitrate at ambient conditions rapidly and cautiously emit toxic ammonia and nitric acid gasses that evaporate to the surrounding environment [27, 28]. The expected evaporation of these toxic gasses from aerosols in rainy conditions and their inhalation can be a probable factor for respiratory asthma in the Ahvaz outbreak. Moreover, nitrate ion produced by inhaled nitric acid gas is a strong oxidant and can cause vast oxidation in affected individuals [17-29]. Even though in a study it was shown that the total concentration of 5 mg/m^3 of ammonium nitrate in aerosols does not cause any pulmonary problems in a voluntary group, but in the case of Ahvaz outbreaks with thousands time more quantities of ammonium nitrate, severe respiratory complications, and even lethal effects will be expected [28, 30, 31].

Cough, bronchospasm, dyspnea, chest tightness, wheezing, choking, ocular and throat irritations are reported similarly for Ahvaz asthma outbreak and intoxication by nitrates. It is also shown that nitrate can pass the respiratory tract to the bloodstream and neutralize by hemoglobin which subsequently leads to methemoglobin formation and methemoglobinemia [32-35].

Methemoglobin, in contrast to hemoglobin, cannot bind oxygen and transport it to tissues. Methemoglobinemia is a severe disease with symptoms depending on the total concentration of methemoglobin, including bronchospasm, dyspnea, chest tightness through more severe manifestations of arrhythmia and death [32-35].

In the present work, we quantified nitrate ions carried by indoor dust during October 2015 and investigated possible effects of nitrate ions on human adult hemoglobin to elucidate the probable mechanism behind the asthma-like autumn outbreaks in Ahvaz city.

2. Materials and Methods

Dust samples

To assess the contamination of dust by ammonium nitrate, we collected dust samples from different places and different cities, including Ahvaz, Ramhormoz, Abadan, Andimeshk, and Susangerd from November 2015 to December 2016 [36]. In this work, the precipitated dust on smooth surfaces in the indoor environment of buildings in Shahid Chamran University were used. The segregated samples of 200 mg dust were suspended in 2 mL of double distilled and deionized water for about one hour and then shook thoroughly at room temperature. The suspension was then centrifuged at 3000 rpm for 15 minutes, and the clear supernatants were separated and used for further analyses. It is essential to mention that the concentration of PM_{10} in this period was more than 255 mg/m^3 [10].

Nitrate determination

The nitrate concentration was measured by ion chromatography method with a Metrohm 761 Compact IC set in the Department of Geology, Faculty of Geosciences, Shahid Chamran University of Ahvaz, as reported before [33, 37].

Hemoglobin sample

Heparinized fresh blood samples were obtained from healthy donors without any backgrounds of asthma or cardiovascular disease after 8 hours fasting period. They were washed two times with ten volumes of saline. The washed blood then lysed was by three volumes of cold deionized water. Hemoglobin was extracted and stripped from anions by CM-Sephadex cation exchanger at pH 6.5 and Sephadex G-25 column, respectively, as reported before.38 Hemoglobin samples were used in 0.1 M phosphate buffer pH 7.0 throughout spectroscopic experiments [38]. Since hemoglobin samples are sensitive to autooxidation; the blood samples were prepared on the day of the experiment freshly.

Spectroscopic studies

Samples with 1.5 mL volume of fresh hemoglobin solution containing about 2-4 mg/mL protein were used for the spectroscopic assay. Hemoglobin spectra in the range of 200-750 nm before and after the addition of 0.3 mL of dust supernatant were obtained using Biowave II spectrophotometer, Biochrom LTD, Cambridge England. The progression in absorbance at 630 nm was followed by time scan mode for about 1 hour [39].

Methemoglobin determination

In hemoglobin solution, the concentration of oxy-, deoxy- and met-hemoglobin species could be calculated at pH 7 using the Equations 1, 2 and 3.

1. $[Oxy]=(1.0154A_{576}-0.2771A630-0.742A_{560})\times10^{-4}$

2. $[Deoxy]=(1.357A_{560}-0.737A576-0.625A_{630})\times10^{-4}$

3. $[Met]=(2.6829A_{630}-0.174A576-0.3614A_{560})\times10^{-4}$

It should be mentioned that oxyhemoglobin concentration at each moment depends mainly on the absorbance at 576 nm, deoxyhemoglobin depends on absorbance at 540 nm, and methemoglobin depends on the absorbance at 630 nm [38].

3. Results and Discussion

According to the data obtained from Knoema, the comprehensive source for integrated global data, Iran produced and used 102077 tones of ammonium nitrate as fertilizer in agricultural projects during 2013. This is the year that the first reported asthma outbreak in Ahvaz took place in the autumn season with more than 20000 hospital admissions. Based on the data obtained from Knoema in 2013, there is more than 917 percent increase in ammonium nitrate production compared to 2012 that correlates with more severe asthma of 2013 outbreak compared to 2012 [23].

Our ammonium nitrate determination indicates that the concentration of nitrate in dust collected from indoor spaces during this study was 268 ppm, which is five times higher than levels allowed as dissolved nitrate in the bloodstream (50 ppm) or as airborne pollutant [40].

Accordingly, agricultural ammonium nitrate seemed to be the primary source of nitrate in the dust. If our hypothesis regarding the involvement of ammonium nitrate in asthma outbreak comes true, based on data obtained from Knoema, there should have been unreported outbreaks in Khuzestan during 2006-2008. Figure 1 shows the absorption spectra for normal oxyhemoglobin and abnormal methemoglobin formed by the addition of 300 mL dust supernatant after one hour. As it is evident, the oxyhemoglobin spectrum in the 350-700 nm region contains α band at about 576 nm and b β band at about 540 nm wavelengths, and a Soret band at about

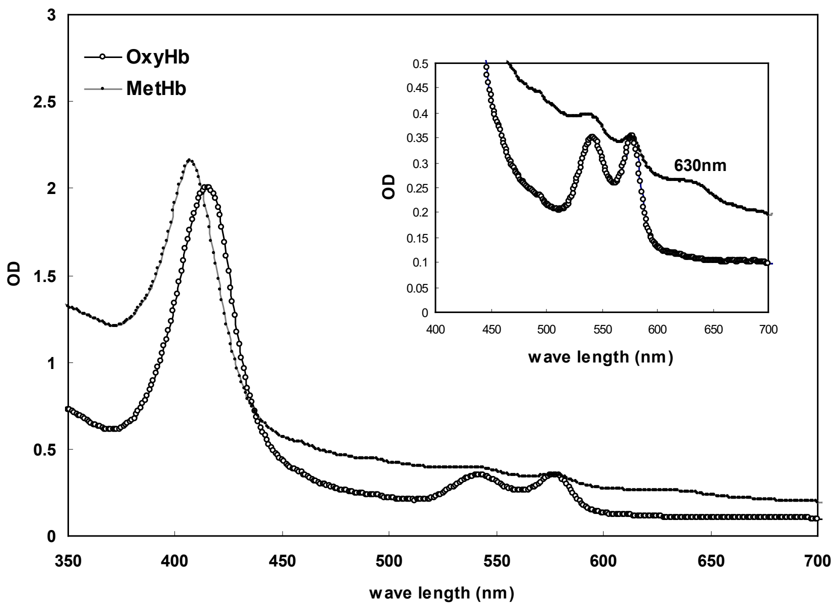

Figure 1. Absorption spectra for oxyhemoglobin and methemoglobin for human hemoglobin before and 1 hour after addition of 300 mL of dust supernatant in 0.1 M phosphate buffer pH 7 in the range of 350-700 nm wavelengths

410 nm. All are assigned to $\pi \rightarrow \pi^*$ electron transitions in the heme group of hemoglobin. In the case of methemoglobin formation, a small band appears at 630 nm that belongs to $n \rightarrow \pi^*$ electron transitions of the heme group. Based on our findings, the addition of 300 mL of nitrate-containing dust supernatant undoubtedly, leads to methemoglobin formation in the test tube, the phenomenon we hypothesized that happens in affected individuals [38]. Methemoglobin formation decreases oxygen saturation and leads to hypoxemia. This severe state causes symptoms such as headache, bronchospasm, shortness of breath, coughing, and wheezing presentations, similar to those reported for asthma outbreak in Ahvaz [1, 4, 23].

Figure 2 illustrates the time scan change in methemoglobin concentration after the addition of 300 mL of dust supernatant in 1 hour. As it is clear, there are two distinct phases in methemoglobin formation. The first phase is speedy and completes in one minute. The percentage

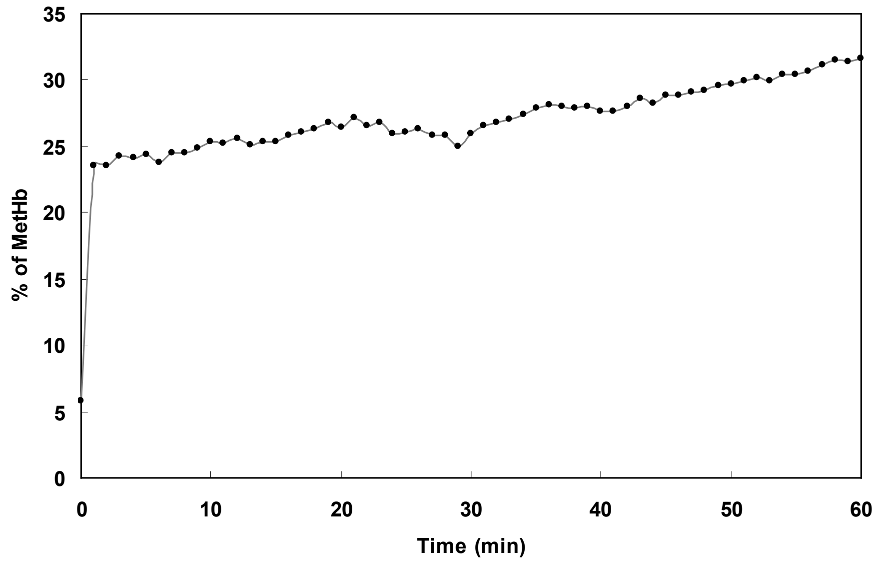

Figure 2. Time scan determination of methemoglobin (%) determined after addition of 300 mL of dust supernatant determined in hemoglobin solution with about 2-3 mg/mL protein in 0.1 M phosphate buffer pH 7

of methemoglobin in this phase increases from ~2% to 18%, which could be symptomatic. In the next phase, the percentage of methemoglobin increases gradually to about 8% after 60 minutes. This increment could continue to higher values after longer times results in more severe symptomatic hypoxemia.

We suggest that a dramatic increase in ammonium nitrate application in agriculture (https://knoema.com) during the years of outbreaks of Ahvaz coincides with the increased annual outbreak of autumn respiratory asthma, which accompany thousands of hospital admissions as serious public health in Khuzestan Province, southwest of Iran [1-5]. Previous literature also extensively indicated that particulate matter increased dramatically during this period [3, 10, 12]. There are also many reports showing increased anthropologic toxic pollutants in Ahvaz correlate with respiratory and cardiovascular diseases [41-44]. It is also shown that indoor PM particles are originated from outdoor particles carrying the same toxic materials [3, 45]. In contrast to $PM_{2.5}$ and PM_1, PM_{10} is said to carry five-fold larger quantities of nitrate. Therefore, we suspected it to be the cause behind the annual outbreak of Ahvaz asthma [22, 26]. High concentration of 268 ppm in dust supernatant confirms our claim in this context.

The first rainfall is also believed to be the flashpoint for this outbreak, particularly when accompanied by thunder, lightning, and surface wind blow. This could also be understood entirely by decomposition of ammonium nitrate or aerosol formation in this condition as postulated accordingly [16, 22, 23]. Nitrate emanated from industrial sources seemed harmless for the problem as the industrial activities had started more than 50 years before asthma outbreaks occurred.

4. Conclusion

If our findings and hypothesis regarding the intervention of ammonium nitrate in asthma outbreak in Ahvaz are confirmed through methemoglobin determination in the blood of affected patients, then the higher applications of ammonium nitrate in agricultural lands would lead to higher environmental contamination by ammonium nitrate, which in turn would end up in more tragic asthma outbreaks in Ahvaz.

Ethical Considerations

Compliance with ethical guidelines

The ethical guideline approved by the Research Ethics Committee of Shahid Chamran University of Ahvaz (Iran) was considered throughout this work.

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Conflict of interest

There are no conflicts of interest to disclose.

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References

[1] Forouzan A, Masoumi K, Haddadzadeh Shoushtari M, Idani E, Tirandaz F, Feli M, et al. An overview of thunderstorm-associated asthma outbreak in southwest of Iran. J Environ Public Health. 2014; 2014:504017. [DOI:10.1155/2014/504017] [PMID] [PMCID]

[2] Dabrera G, Murray V, Emberlin J, Ayres JG, Collier C, Clewlow Y, et al. Thunderstorm asthma: an overview of the evidence base and implications for public health advice. QJM. 2013; 106(3):207-17. [DOI:10.1093/qjmed/hcs234] [PMID]

[3] Hassanvand MS, Naddafi K, Faridi S, Arhami M, Nabizadeh R, Sowlat MH, et al. Indoor/outdoor relationships of PM10, PM2.5, and PM1 mass concentrations and their water-soluble ions in a retirement home and a school dormitory. Atmos Enviro. 2014; 82:375-82 [DOI:10.1016/j.atmosenv.2013.10.048]

[4] Idani E, Raji H, Madadizadeh F, Cheraghian B, Haddadzadeh Shoshtari M, Dastoorpoor M. Prevalence of asthma and other allergic conditions in adults in Khuzestan, southwest Iran, 2018. BMC Public Health. 2019; 19:303 [DOI:10.1186/s12889-019-6491-0] [PMID] [PMCID]

[5] Carrillo G, Patron MJP, Johnson N, Zhong Y, Lucio R, Xu X. Asthma prevalence and school-related hazardous air pollut-

ants in the US-Mexico border area. Environ Res. 2018; 162:41-8. [DOI:10.1016/j.envres.2017.11.057] [PMID]

[6] Heidari-Farsani M, Shirmardi M, Goudarzi G, Bakhtiari-vand NA, Ahmadi-Ankali K, Zallaghi E, et al. The evaluation of heavy metals concentration related to PM10 in ambient air of Ahvaz city, Iran. J Adv Environ Health Res. 2013; 1(2):120-8. [doi: 10.22102/jaehr.2013.40133]

[7] Bagheri A. A descriptive study on how to control, prevent and combat pollutant factors (A case study, Ahvaz city in Khuzestan province, Iran). Int Res J Appl Basic Sci. 2015; 9(3):262-7. https://irjabs.com/files_site/paperlist/r_2511_150227144926.pdf

[8] Arvin AA, Rahimi M, Qoli MA. Deadly Tsunami and the negative impact on Iran border regions (Case study: Ahvaz, Iran). J NovAppl Sci. 2014; 3(7):719-23. http://jnasci.org/wp-content/uploads/2014/07/719-723.pdf

[9] Bahrami F, Kermani M, Aghaei M, Karimzadeh S, Salahshour Arian S, Shahsavani A, et al. [Estimation of diseases and mortality attributed to NO2 pollutant in five metropolises of Iran using Air Q model in 2011-2012 (Persian)]. J Mazandaran Univ Med Sci. 2015; 24(121):239-49. http://eprints.iums.ac.ir/5773/

[10] Parvizimehr A, Norouzian Baghani A, Hoseini M, Sorooshian A, Cuevas-Robles A, et al. On the nature of heavy metals in PM_{10} for an urban desert city in the Middle East: Shiraz, Iran. Microchem J. 2020; 154:104596. [DOI:10.1016/j.microc.2020.104596]

[11] Zallaghi E, Goudarzi G, Geravandi S, Mohammadi MJ. Epidemiological indexes attributed to particulates with less than 10 micrometers in the air of Ahvaz city during 2010 to 2013. Health Scope. 2014; 3(4):e22276 [DOI:10.17795/jhealthscope-22276]

[12] Goudarzi G, Geravandi S, Mohammadi MJ, Vosoughi M, Ahmadi Angali K, Zallaghi E, et al. Total number of deaths and respiratory mortality attributed to particulate matter (PM10) in Ahvaz, Iran during 2009. Int J Env Health Eng. 2015; 4(1):33. [DOI: 10.4103/2277-9183.163978]

[13] Sawyer K, Mundandhara S, Ghio AJ, Madden MC. The effects of ambient particulate matter on human alveolar macrophage oxidative and inflammatory responses. J Toxicol Environ Health A. 2010; 73(1):41-57 [DOI:10.1080/15287390903248901] [PMID]

[14] Snow SJ, De Vizcaya-Ruiz A, Osmomio-Vargas A, Thomas RF, Schladweiler MC, McGee J, et al. The effect of composition, size, and solubility on acute pulmonary injury in rats following exposure to mexico city ambient particulate matter samples. J Toxicol Environ Health A. 2014; 77(19):1164-82. [DOI:10.1080/15287394.2014.917445] [PMID]

[15] Tsai SS, Yang CY. Fine particulate air pollution and hospital admissions for pneumonia in a Subtropical City: Taipei, Taiwan. J Toxicol Environ Health A. 2014; 77(4):192-201. [DOI:10.1080/15287394.2013.853337] [PMID]

[16] Gerivani H, Lashkaripour GR, Ghafoori M, Jalali N. [The source of dust storm in Iran: A case study based on geological information and rainfall data (Persian)]. Carpath J Earth Env. 2011; 6(1):297-308. https://profdoc.um.ac.ir/paper-abstract-1019133.html

[17] Ashrafi K, Shafiepour-Motlagh M, Aslemand A, Ghader S. Dust storm simulation over Iran using HYSPLIT. J Environ Health Sci Eng. 2014; 12:9. [DOI:10.1186/2052-336X-12-9] [PMID] [PMCID]

[18] Draxler RR, Gillette DA, Kirkpatrick JS, Heller J. Estimating PM10 air concentrations from dust storms in Iraq, Kuwait and Saudi Arabia. Atmos Environ. 2001; 35(25):4315-30. [DOI:10.1016/S1352-2310(01)00159-5]

[19] Goudie AS, Middleton NJ. Saharan dust storms: nature and consequences. Earth Sci Rev. 2001; 56(1-4):179-204. [DOI:10.1016/S0012-8252(01)00067-8]

[20] Leon JF, Legrand M. Mineral dust sources in the surroundings of the North Indian Ocean. Geophys Res Lett. 2003; 30(6). [DOI:10.1029/2002GL016690]

[21] Pope CA 3rd, Dockery DW. Health effects of fine particulate air pollution: Lines that connect. J Air Waste Manag Assoc. 2006; 56(6):709-42. [DOI:10.1080/10473289.2006.10464485] [PMID]

[22] Geravandia S, Goudarzic G, Vosoughid M, Salmanzadehe S, Mohammadib MJ, Zallaghif E. Determination of behavior particulate matter less than 10 microns and effects on human health in Ahvaz, Southwest Iran. Arch Hyg Sci. 2015; 4(2):64-72. http://jhygiene.muq.ac.ir/article-1-41-en.html

[23] Idani E, Dastoorpoor M, Goudarzi G, Khanjani N. Severe outbreaks of respiratory syndromes following autumn rainfall in Khuzestan. Arch Iran Med. 2016; 19(12):884-5. [PMID]

[24] Mirhosseini SH, Birjandi M, Zare MR, Fatehizadeh A. Analysis of particulate matter (PM10and PM2.5) concentration in Khorramabad city. Int J Env Health Eng. 2013; 2:3. [DOI:10.4103/2277-9183.106635]

[25] Bauer SE, Koch D, Unger N, Metzger SM, Shindell DT, Streets DG. Nitrate aerosols today and in 2030: A global simulation including aerosols and tropospheric ozone. Atmos Chem Phys. 2007; 7(2):5553-93 [DOI:10.5194/acp-7-5043-2007]

[26] Rezaei M, Salimi A, Taghidust M, Naserzadeh P, Goudarzi G, Seydi E, et al. A comparison of toxicity mechanisms of dust storm particles collected in the southwest of Iran on lung and skin using isolated mitochondria. J Toxicol Environ Chem. 2014; 96(5):814-30. [DOI:10.1080/02772248.2014.959317]

[27] Kleinman MT, Linn WS, Michael RM, Jones P, Hackney JD. Effect of Ammonium Nitrate Aerosol on human respiratory function and symptoms. Environ Res. 1980, 21(2):317-26 [DOI:10.1016/0013-9351(80)90033-X]

[28] Larson TV, Taylor GS. On the evaporation of ammonium nitrate aerosol. Atmos Environ. 1983; 17(12):2489-95. [DOI:10.1016/0004-6981(83)90074-4]

[29] Goudarzi G, Mohammadi MJ, Ahmadi Angali K, Neisi AK, Babaei AA, Mohammadi B, et al. [Estimation of health effects attributed to NO_2 exposure using airQ model (Persian)]. Arch Hyg Sci. 2012; 1(2):59-66. https://www.sid.ir/en/Journal/ViewPaper.aspx?ID=307374

[30] Shahsavani 30 A, Naddafi K, Jaafarzadeh Haghighifard N, Mesdaghinia A, Yunesian M, Nabizadeh R, et al. Characterization of ionic composition of TSP and PM10 during the Middle Eastern Dust (MED) storms in Ahvaz, Iran. Environ Monit Assess. 2012; 184(11):6683-92. [DOI:10.1007/s10661-011-2451-6] [PMID]

[31] Shahsavani 31 A, Naddafi K, Jafarzade Haghighifard N, Mesdaghinia A, Yunesian M, Nabizadeh R, et al. The evaluation of PM10, PM2.5, and PM1 concentrations during the Middle Eastern Dust (MED) events in Ahvaz, Iran, from april through september 2010. J Arid Environ. 2012; 77:72-83 [DOI:10.1016/j.jaridenv.2011.09.007]

[32] Kohn MC, Melnick RL, Ye F, Portier CJ. Pharmacokinetics of sodium nitrite-induced methemoglobinemia in the rat. Drug Metab Dispos. 2002; 30(6):676-83. [DOI:10.1124/dmd.30.6.676] [PMID]

[33] Chitsazan M, Faryabi M, Zarasvandi A, Negarestani A. Evaluation of the spatio-temporal variability in river and groundwater interactions, an example from South West of Iran. Int J Sci Res Environ Sci 2015; 3(4):147-58 [DOI:10.12983/ijsres-2015-p0147-0158]

[34] Shihana F, Dissanayake DM, Buckley NA, Dawson AH. A simple quantitative bedside test to determine methemoglobin. Ann Emerg Med. 2010; 55(2):184-9 [DOI:10.1016/j.annemergmed.2009.07.022] [PMID] [PMCID]

[35] Gorguner M, Akgun M. Acute inhalation injury. Eurasian J Med. 2010; 42(1):28-35 [DOI:10.5152/eajm.2010.09] [PMID] [PMCID]

[36] Soleimani N, Faridnouri H, Dayer MR . The effect of dusts on liver enzymes and kidney parameters of serum in male rats in Khuzestan, Iran. J Chem Health Risks. 2020; 10(4):315-26. [doi: 10.22034/jchr.2020.1902789.1148]

[37] Chitsazan M, Rezapour Tabari MM, Eilbeigi M. Analysis of temporal and spatial variations in groundwater nitrate and development of its pollution plume: A case study in Karaj aquifer. Environ Earth Sci. 2017; 76:391 [DOI:10.1007/s12665-017-6677-7]

[38] Dayer MR, Moosavi-Movahedi AA, Dayer MS. Band assignment in Hemoglobin porphyrin ring spectrum: Using four-orbital model of Gouterman. Protein Pept Lett. 2010; 17(4):473-9 [DOI:10.2174/092986610790963645] [PMID]

[39] Whitehead Jr RD, Mei Z, Mapango C, Jefferds MED. Methods and analyzers for hemoglobin measurement in clinical laboratories and field settings. Ann N Y Acad Sci. 2019; 1450(1), 147-71. [DOI:10.1111/nyas.14124] [PMID] [PMCID]

[40] Ward MH, Jones RR, Brender JD, de Kok TM, Weyer PJ, Nolan BT, et al. Drinking water nitrate and human health: An updated review. Int J Environ Res Public Health. 2018; 15(7):1557. [DOI:10.3390/ijerph15071557] [PMID] [PMCID]

[41] Alavi SM, Bakhtiyariniya P, Eghtesad M, Salmanzadeh S. Prevalence of pulmonary tuberculosis before and after soil dust in Khuzestan, South West Iran. Caspian J Intern Med. 2014; 5(4):190-5. [PMCID]

[42] Goudarzi G, Zallaghi E, Neissi A, Ahmadi Ankali K, Saki A, Babaei AA, et al. [Cardiopulmonary mortalities and chronic obstructive pulmonary disease attributed to ozone air pollution (Persian)]. Arch Hyg Sci. 2013; 2(2):62-72. https://www.sid.ir/en/journal/ViewPaper.aspx?id=438584

[43] Goudarzi G, Geravandi S, Foruozandeh H, Babaei AA, Alavi N, Vosoughi Niri M, et al. Cardiovascular and respiratory mortality attributed to ground-level ozone in Ahvaz Iran. Environ Monit Assess. 2015; 187(8):487 [DOI:10.1007/s10661-015-4674-4] [PMID]

[44] Goudarzi G, Geravandi S, Naimabadi A, Mohammadi MJ, Neisi AK, Taghavirad SS, et al. Cardiovascular deaths related to Carbon monoxide Exposure in Ahvaz, Iran. Iran J Health Saf Environ. 2014; 1(3):126-31. http://www.ijhse.ir/index.php/IJHSE/article/view/50

[45] Soleimani Z, Parhizgari N, Dehdari Rad H, Akhoond MR, Kermani M, Bagherian Marzouni M, et al. Normal and dusty days comparison of culturable indoor airborne bacteria in Ahvaz, Iran. Aerobiologia. 2015; 31:127-41 [DOI:10.1007/s10453-014-9352-4]

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