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Modeling air pollution emissions (CO, SO_2, and NO_2) from steel production process

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ABSTRACT

Controlling and decreasing the consequences resulted from the emission of pollutants require modeling the dispersion pattern of these gases from their sources and investigating their emission range and related environmental effects. Considering the importance of steel industry as one of the evaluative criteria of countries' industrialization in the world, after introducing and investigating the processes and pollutants of this industry, a case study was conducted on the dispersion of pollutants from Takestan Steel Production Company. Raw data were converted into tangible data using computer software and then were presented in this project. To this end, PHAST 6.54 advanced software, which is one of the best and most accurate tools for modeling dispersion of materials in the environment, was used. In the present analysis, besides modeling CO dispersion, in order to gain better understanding about its concept of emission, two other major pollutants emitted from stacks of steel production factories, i.e. SO2 and NO2, were also modeled.

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INTRODUCTION

One of the crises of today's world which has been resulted from industrial activities is environmental pollution that has endangered the lives and properties of people. There are different forms of pollution including noise, water, air, soil, etc. What is obvious in this regard is related to air pollution and method of modeling emission of pollutants in air, which is one of the greatest challenges of industrial environments with high population density and also mega cities. The selected industry in this study was steel production; in this project, the pollutants emitted from stacks of Takestan Steel Factory (CO gas exiting from the stack) were investigated and analyzed. There are numerous methods for modeling the emission of toxic and pollutant gases in air and also predicting their emission manner, which include using advanced software; in this work, PHAST software was used for making such prediction.

Emission of CO toxic gas from stacks of Takestan Steel Factory was modeled by determining objectives, selecting the scenario, analyzing the conditions, and also utilizing data and information. Furthermore, to gain better understanding about the emission of this gas, two other important pollutants of this industry as SO_2 and NO_2 were also modeled. Finally, evaluation, conclusion, solutions, and recommendations were presented.

Objectives:

– Determining the expansion range of CO toxic gas along with two other important pollutants produced by steel production unit: SO_2 and NOx

– Identifying risks resulted from harmful concentrations on the inhabitants of the industrial park and its surrounding area

– Investigating whether the industrial unit has been correctly located and its safe perimeter has been safely observed or not

– Proposing solutions for controlling and decreasing the consequences resulted from the emission of pollutants in steel industry

Data and information:

Below, process information, physical characteristics of the model, and weather conditions of Takestan region is used for modeling the emission of gases.

1.1. Meteorological information (Ghiasaddin *et al*., 2006; Omidkhah *et al*., 2006)

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Regarding the selection of weather conditions, critical conditions were considered. Therefore, November with minimum wind velocity (approximately 3.08 m/s), prevailing wind direction of135, relatively low mean temperature of8.7°C, and mean relative humidity of 61% were chosen. Also, the most stable atmospheric class related to this month, which was E atmospheric class, was applied.

1.2. Process information and physical characteristics(Edrisi *et al*., 2005)

Process specification and information were related to the pre-heat furnace stack of rolling unit in Alborz Takestan Steel Factory. Process information and characteristics of the mentioned stack which were required for modeling are presented in Table 1.

Table 1: Process information and characteristics of stack

Gasses flow rate	Exhaust gas temperature	Chimney height	The total flow rate of the exhaust gas standard conditions	Emission of NO2 Gas	Emission of SO2 gas	Emission of CO gas	Diameter chimney	Factor
m/s	C0	M	M3/s	gr/s	gr/s	gr/s	Cm	Unit
2.67	186.7	25	4.72	0.8	13.7	2.16	150	Amount

Selecting the scenario(Omidkhah *et al*., 2005)

In order to define the possible scenario and according to the title of this article, which was modeling the emission of CO gas from steel production factories, the emission pattern of this gas from the site's stack was continuously studied as the main scenario. Also, due to the importance of two other pollutants produced by steel production unit as SO2 and NOx and also the comparison of their emission with that of CO gas, two other scenarios were considered for the emission pattern of these two gases from the same stack. Evaluation of the dispersion of the two other gases not only could present more information about the behavior of pollutants, but also provides the reader with better understanding of the concept of CO emission.

1.3. Using PHAST software for modeling (Abdolhamidzadeh *et al*., 2010)

Consequence modeling includes modeling the release of materials in the environment and then modeling the consequences resulted from toxicity, combustion, or explosion of these materials. Today, due to the complexity of equations and time-consuming nature of their solution, this process is done by computer software. In the modeling section, some software which is capable of calculating the emission of materials is introduced.

PHAST (process hazard analysis software tool) is a comprehensive analytical tool and one of the most conventional tools for modeling the dispersion of toxic and air pollutant gases in European countries. Owing to its easy and flexible use, this software enables users to analyze various values for an extensive range of model parameters. Level of emission and its location according to the given information can be determined on GIS and Google Earth maps and alarming is done in case.

2. ERPG criterion (SalehiArtimani *et al*., 2012; salehiartimani, 2012)

- ERPG-1: is the maximum concentration of chemical in air, to which all people can be exposed for 1 h without any trouble or feeling any undesirable smell.
- ERPG-2: is the maximum concentration of chemical in air, to which all people can be exposed for 1 h without suffering from any serious or irreparable damage or inability to takingsafety measures.
- ERPG-3: is the maximum concentration of chemical in air,to which all people can be exposed for 1 h without endangering their lives.

Modeling

Modeling emission of CO gas from stack of TakestanSteel Factory (Pandya, 2012) (Ruggieri *et al*., 2012)

For the purpose of modeling CO gas from the stack, data and information in AQI tables were used as the input of PHAST 6.54 advanced software. As can be seen in Figure 1, the concentration value of 4.4 ppm in blue demonstratesindex of 50 and good region in terms of health level, another layer with the concentration value of 9.4 ppm in yellow denotesindex of 100 and average region in terms of health level, the next concentration level with 15.4 ppm and green color shows 200and unhealthy region, and finally the closest area to the stack in red with the concentration of 30.4 ppm shows 300, which is considered very unhealthy, even dangerous.

Regarding Figure 1 and Map1, the following points were considered:

1) Considering that the concentration of gas varies at different distances, the results are only shown for the selected concentrations.

2) Considering that wind direction varies during a day, therefore, the top-view results for the effect zonesare drawn in circles and prevailing wind direction is given in ellipticalshapes.

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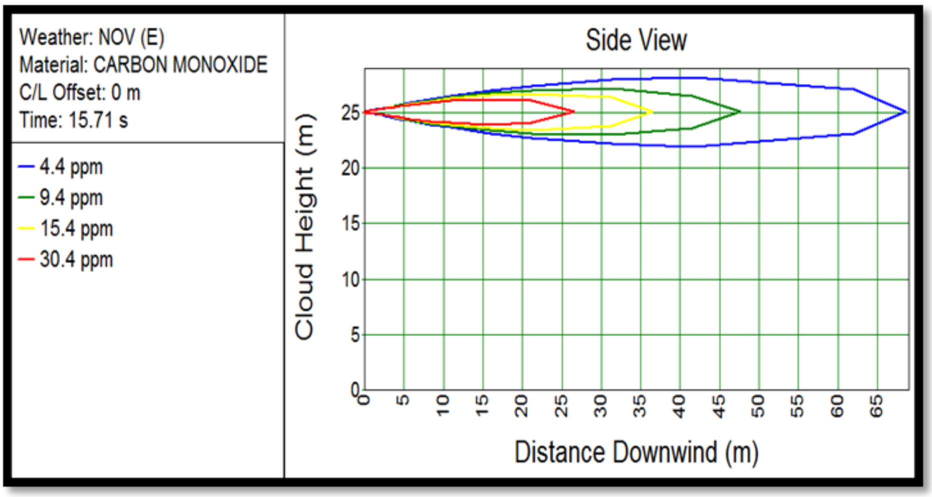

Fig. 1: Side view of emission of CO gas from stack of Takestan Steel Company in November

Map. 1: Top view of emission of CO gas from stack of Takestan Steel Factory at stack level in November

As determined in the section explaining Figure 1 and Map 1, the concentration profile of CO remained constant after 15.71 sec at the defined concentration intervals (the minimum of which was up to the concentration of 4.4 ppm); since then, no change occurred in the concentration profile, which can be due to the continuous process of gas emission from the stack and lack of change in the effective variables in the gas emission including gas mass flow rate, weather conditions, stack height, etc.

Results of the modeling in Figure 1 and Map1 demonstrate that, considering the25 m height of the stack, CO gas can only descend to the height of 22 m after emission and cannot reach the ground, the main cause of which can be its less weight than air. Even it can be pointed out that this gas (with molecular weight of 28) has approximately the same weight as air (with molecular weight of 29).Thus, the emission of this gas is categorized in the release group of gases with positive and neutral buoyancy and it can be expected that the motion of CO gas after emission is not toward the ground if the output mass flow rate is not high and the stack has suitable height from the ground level. In fact, the results of modeling in the side view for CO emission from this stack (Figure 1) demonstrates the release of gases with positive and neutral buoyancy.

As is obvious in Figure 1, risky weather conditions only existed in an area with the height of more than 23 m and it can be said that unhealthy weather conditions existed up to the height of about 27 m and distance of 36 m from the stack. The important result is that no CO concentration reaches the ground, even under the worst condition, and the performance of authorities of Takestan Steel Factory in terms of applying the equipment, reducing air pollution, and also selecting appropriate stack height is very desirable. Owing to these appropriate policies, humans and other organism’s aroundthe industrial environment will not be exposed to such a dangerous gas.

Modeling emission of SO_2 from stack of Takestan Steel Factory

Emission of SO_2 gas from the stack of the factory depends on weather conditions, stack characteristics in the factory, gas flow rate, etc. In this section, the effect zone of SO_2 gas emitted from the stack of this factory in

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November (the most stable condition) for the concentrations of 0.034, 0.144, 0.304, and 0.605 ppm corresponding to indices of 50, 100, 200, and 500 indicated the health level of good, average, unhealthy, and dangerous, respectively; this information was presented on the actual maps of the factory using PHAST 6.54 advanced software. The zones related to indices of 50, 100, 200, and 500 were denoted in blue, green, yellow, and red, respectively. Considering that this gas is heavier than air, it gets closer to the ground after emission from the stack, as expected. Results of modeling SO2 gas are presented in Figure 2 and Maps 2 and 3.

While demonstrating the above-mentioned figure and maps, the following points were considered:

1) Since the concentration of gas varies relative to distance to the ground, therefore, the results are shown for ground level (zero height), stack level (25 m), and concentrations of 0.034, 0.144, 0.304, and 0.605 ppm. Thus, top view maps which do not contain any zone with specific concentration (colored line related to specific concentration) demonstrate that the considered concentration level does not reach the given level. This is clearly obvious in the side-view figure.

2) Considering that wind direction varies during the day, top view results for the effect zones are drawn as circles and prevailing wind direction is givenin elliptical lines.

3)

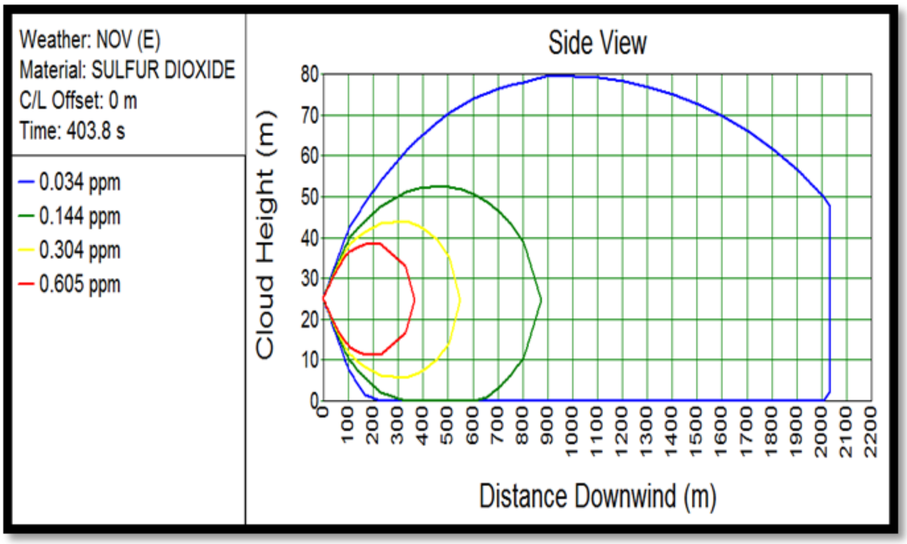
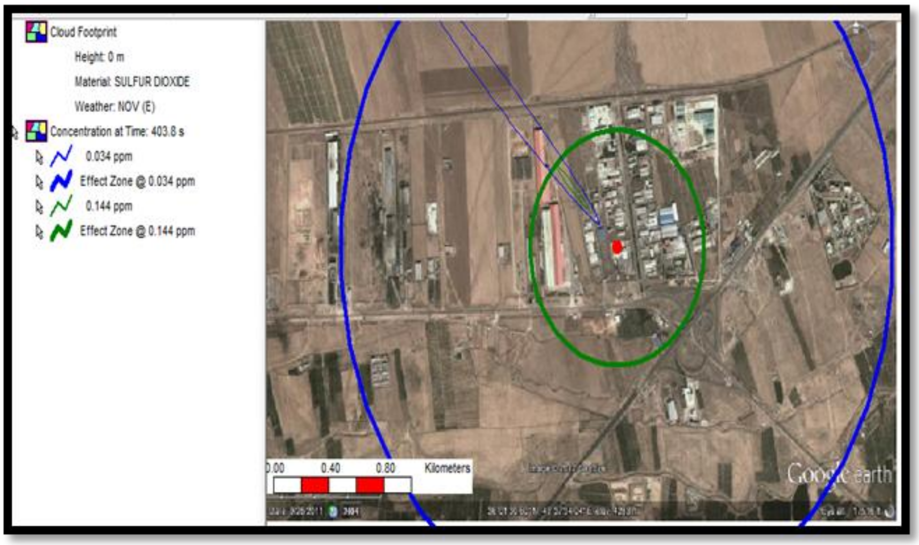
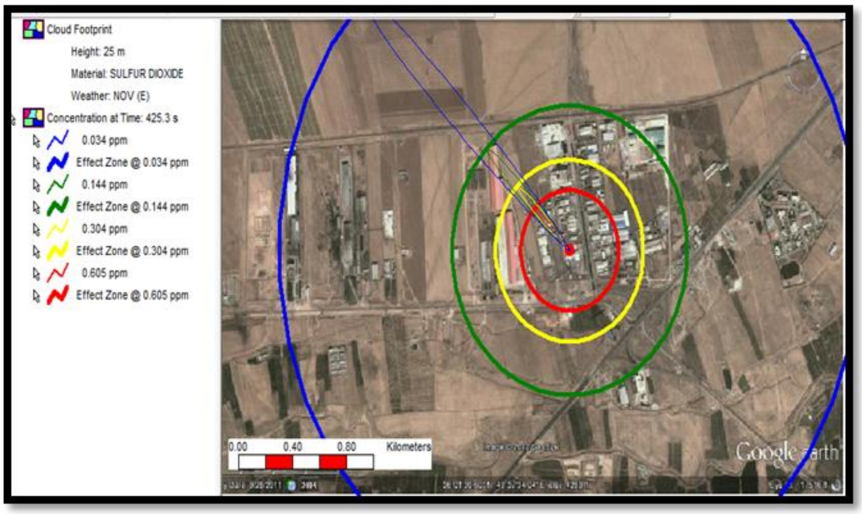


Fig. 2: Side view of SO2 emission from stack of TakestanSteel Factory in November



Map. 2: Emission of SO2 gas from stack of Takestan Steel Factory at ground level in November – top view



Map. 3: Emission of SO2 gas from stack of Takestan Steel Factory at stack level in November – top view

Regarding the results obtained from Figure 2 and Maps 2 and 3, it can be expressed thatSO2gas after the emission from stack of Takestan Steel Factory reached the ground level at the distance of 200 m, the main cause of which can be its higher weight (with molecular weight of64)than air. Emission of this gas is categorized in the release group of gasses with negative buoyancy, which is dispersed at the ground level after emission. Also, relatively high mass flow rate of this gas at 13.7 gr/s and height of stack (25 m)can be considered among other reasons for its descending to the ground level.

Images obtained from the results of modeling SO2 gas implied that dangerous and unhealthy health levels of this gas with the concentration values of 0.605 and 0.304 ppm did not reach the ground; however, other good and average concentration levels with the corresponding values of 0.034 and 0.144 ppm reached the ground at 200 and 300 m downstream of the stack, respectively. SO2 gas with the concentration of 0.144 ppm would affect the people inside the factory park within the distance of 610 m at average healthy level. Then, it would go on with the concentration of 0.35 ppm to the radius of 2020 m and also influence Takestan Islamic Azad University; in fact, based on the air quality values for SO2 gas, this concentration corresponded to good health level and no precaution statements were considered for these two health levels (good and average). Prevailing wind with 135 degrees showed that the gas emission was toward the northwest of the industrial region and mostly the buildings and people within the distance of 2020 m were exposed to this gas. Therefore, Takestan Islamic Azad University was not continuously influenced by SO2 gas emission, due to not being located in the prevailing wind direction.

Modeling emission of NO2 exhausting from stack of Takestan Steel Factory

While modeling the emission of NO2 gas from the stack of this pre-heat furnace, four concentration levels by four different colors (for better detection)were specified for NO2 gas which included the concentration of 0.053 ppm in blue, indicating index of 50 and good region in terms of health level, another layer with the concentration of 0.1 ppm in yellow, indicating100 and average region, next concentration of 0.064 ppm in green showing 200 and unhealthy region, and finally the most dangerous region shown in red, as the closest layer to the stack with the concentration of 1.25 ppm that demonstrated 500 and was considered the dangerous region.

The following assumptions were considered in the demonstration of Figure 3 and Map 4:

1) Since the concentration of gas varies at different distances, therefore results are shown for the selected concentrations in ppm.

2) Considering that wind direction varies during the day, thus top view results for effect zones are drawn as circles and wind direction is shown in the form of elliptical lines.

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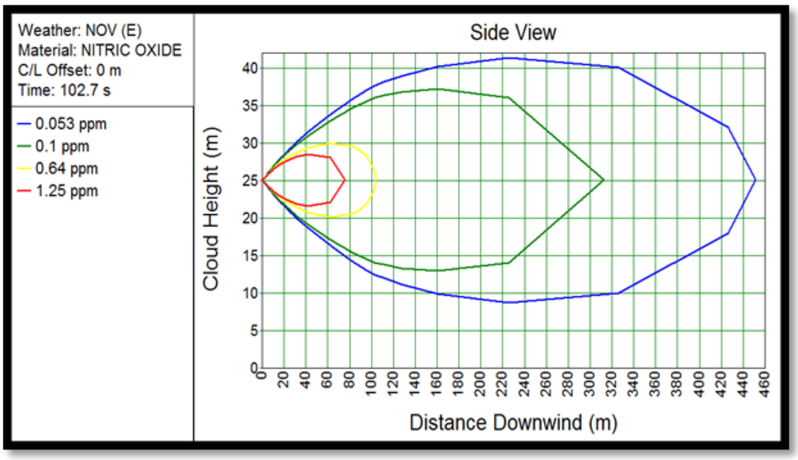
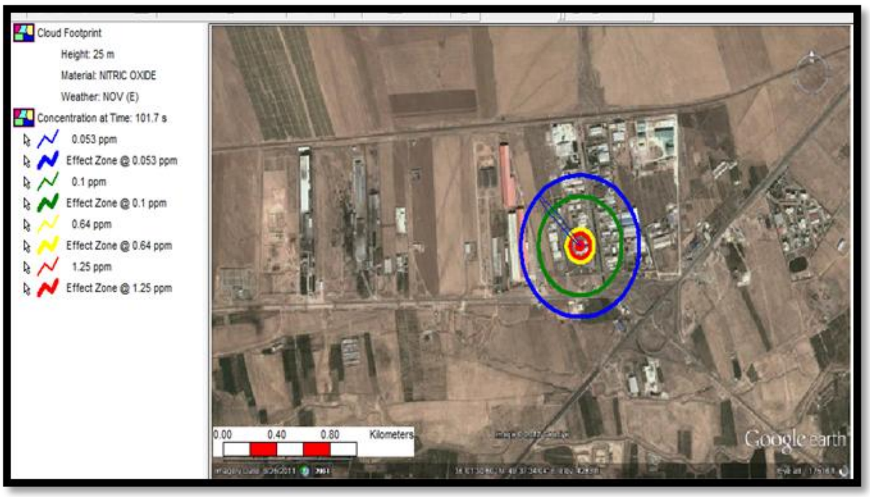


Fig. 3: Side view of emission of NO2 gas from stack of TakestanSteel Factory in November



Map. 4: Top view of dispersion of NO_2 gas from stack of Takestan Steel Factory in November

According to Figure 3 and Map 4 which are the results of modeling the emission of NO2 gas from stack of Takestan Steel Factory, it is observed that, after being emitted from the stack with height of 15 m, this gas could not reach the ground under any circumstances. The main cause may not be related to its less weight, but the negligible mass flow rateof0.8 gr/s. In other words, NO2 gas (with molecular weight of 46)is heavier than air so that it descends to 8 m above the ground, but is diluted with air and cannot reach the ground owing to its low mass flow rate at this height.

Solutions for decreasing air pollution in steel industry after emission of pollutants in environment

- Installing devices containing catalysts for removing pollutants emitting from stacks

Decreasing or removing pollution by catalysts occurs as a result of reactions in which pollutant gases are transformed into harmless gases. By converting CO into CO2, NO2 and NO into N2, and HC into H2 and CO2, the toxic nature of these gases is eliminated. Increasing the height of stacks for the purpose of more dilution of emitted gases with air and preventing the pollutant from reaching the ground

- Optimizing efficiency in energy production processes including increasing efficiency of furnaces
- Applying detector systems
- Expanding continuous monitoring systems in large industrial units and cities
- Evaluating the imposed damage including human, environmental, and financial losses
- Supervising environmental regulations and standards and applying environmental fines
- Observing safe margins for decreasing consequences resulted from emission of pollutants

Conclusion:

According to the studies and calculations of this article, after modeling the dispersion of CO from the stack of pre-heat furnace in the rolling unit of Alborz Takestan Steel Factory, it was concluded that this toxic gas which was dispersed from the height of25 m above the ground level (height of stack) finally descended to the level of 23.Then, it was diluted and fortunately did not reach the ground level. Three following cases can be mentioned among the reasons why this gas does not reach the ground level:

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1- Lightness of CO gas (with molecular weight of 28)compared to air (with molecular weight of 29) or itsalmost the same weight as air

2- Selecting appropriate height for the stack (25 m)

3- Low mass flow rate of CO gas from the stack (2.16 gr/s)

This result indicated that CO gas emitted from the stack of Takestan Steel Factory was harmless for the workers inside this factory. In fact, it should be noted that, although the emission of CO gas from the mentioned factory was safe for people and organisms around the factory, its presence in the atmosphere could cause environmental threats. Therefore, the concentration of Co gas emitting from the stack of factories to the environment should be reduced using appropriate solutions.

Recommendations (Sivacoumar *et al*., 2001)

Growth of industrial activities entails the increased level of dangerous pollutants and the consequence of their emission has turned into a global issue. Thus, based on the importance of this issue, the following cases are recommended:

- Emission of materials causing fire, explosion, and release of toxic materials in the environment should be modeled in different industries and the consequences of their emission should be considered. By evaluating the resulting models, solutions for controlling and decreasing pollutants should be introduced.
- It is also recommended to use the modern ADMS software for modeling dispersion, since it is capable of modeling dust particles.
- Before constructing industrial regions, it is better to specify safe margins by modeling the dispersion pattern of pollutantsin order to decrease the resulting damage and consequences to the minimum level.

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