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Comparing dispersion models of air pollutants (CO, SO_2, and NO_2) emitted from steel production process

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ABSTRACT

Objective: 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 NO_2, were also modeled. Then, the emission manner of these three gases was Compared with each other. Process information and spatial and atmospheric Conditions were Considered as the input data for the software; among the different atmospheric Conditions, the most critical Condition was Conservatively taken into account.

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INTRODUCTION

With the passage of time and growth of industrial activities, their related hazards are also expanding. EConomic development and increasing growth of technology are inventively accompanied by many hazards for human health in daily life, inside or around cities. Discharge and emission of dangerous gases, whether Combustible or toxic, which may mostly occur in the stages of production, maintenance, transportation, and utilization are among the dangerous incidents. 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. In this work, PHAST software was used for the analysis.

Furthermore, to gain better understanding about the emission of this gas, two other important pollutants of this industry as SO2 and NO2 were also modeled. Then, the dispersion manner of these three gasses was compared with each other. Finally, evaluation, Conclusion, solutions, and recommendations were presented. (Edrisi, 2005; SivaCoumar *et al*., 2001).

1. Objectives

– Comparing dispersion manner of CO toxic gas with two other important pollutants produced by steel production unit: SO2 and NOx

– Identifyingrisks 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 (Ghiasaddin *et al*., 2006; salehiartimani, 2012).

Data and information:

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

1.1. Meteorological information (Omidkhah *et al*., 2006; Abdolhamidzadeh *et al*., 2012)

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

Process specification and information were related to the pre-heat furnace stack of rolling unit in AlborzTakestanSteel 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:

In order to define the possible scenario and according to the title of this article, which was modeling the emission of pollutants 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 SO_2 and NO_x 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. (Pandya, 2012; Ruggieri, 2012).

Using PHAST software for modeling:

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 are capable of calculating the emission of materials are 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 determine don GIS and Google Earth maps and alarming is done in case (5).

Modeling:

Modeling emission of CO gas from stack of Takestan Steel Factory

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 demonstrates index of 50 and good region in terms of health level, another layer with the Concentration value of 9.4 ppm in yellow denotes index 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, 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 zones are drawn in circles and prevailing wind direction is given in elliptical shapes.

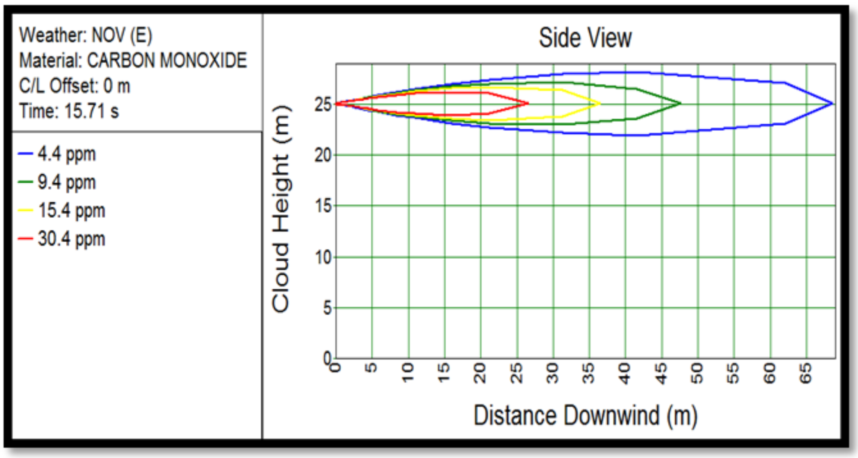

Fig. 1: Side view of emission of CO gas from stack of Takestan Steel Company in November

As determined in the section explaining Figure 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.

Modeling emission of SO2 from stack of Takestan Steel Factory

Emission of SO2 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 SO2 gas emitted from the stack of this factory in 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.

While demonstrating the above-mentioned figure, the following point was considered:

1) Since the Concentration of gas varies relative to distance to the ground, therefore, theresults are shown for ground level (zero height), stack level (25 m), and Concentrations of 0.034, 0.144, 0.304, and 0.605 ppm.

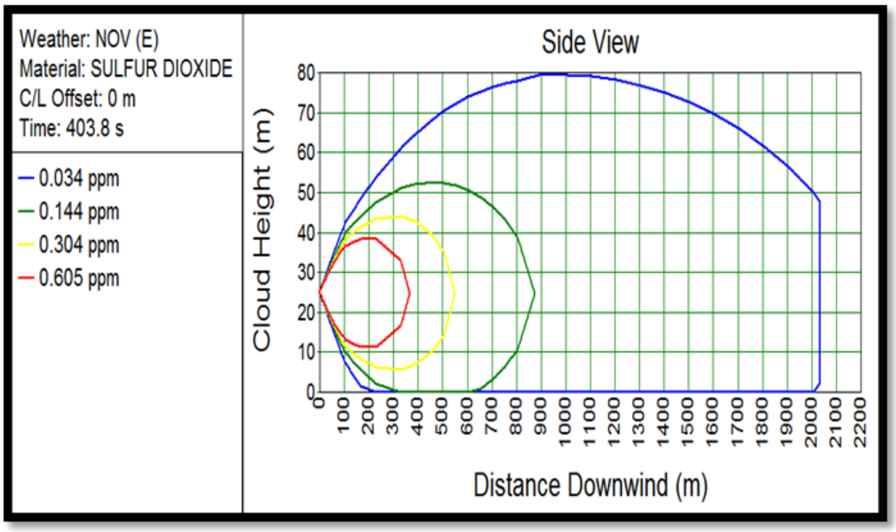

Fig. 2: Side view of SO2 emission from stack of Takestan Steel Factory in November

Regarding the results obtained from Figure 2, 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.

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.

In Figure 3, since the Concentration of gas varies at different distances, therefore results are shown for the selected Concentrations in ppm.

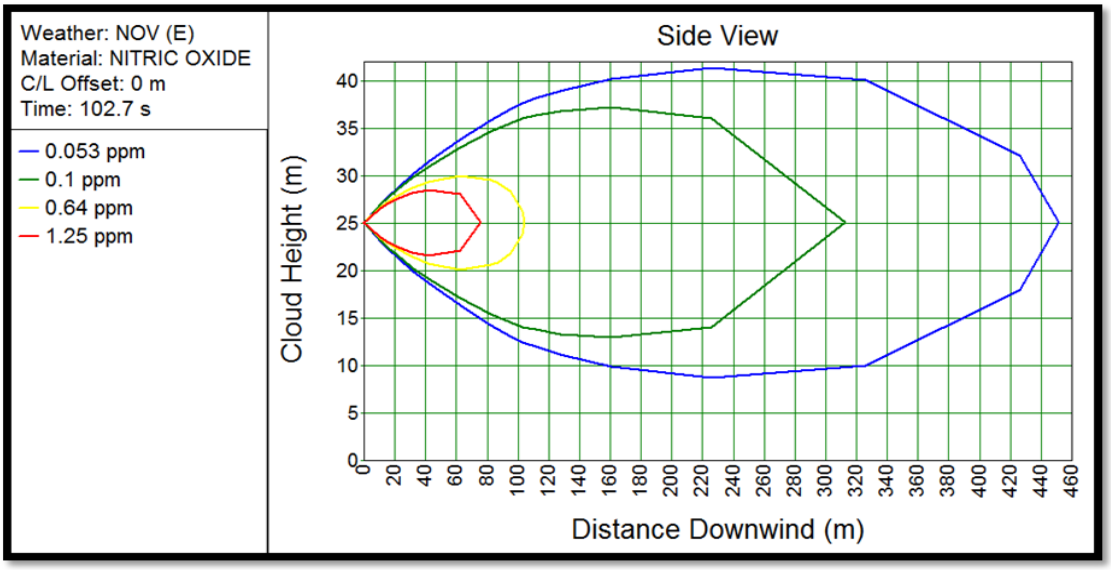

Fig. 3: Side view of emission of NO2 gas from stack of TakestanSteel Factory in November

Results obtained from modeling at three different heights are given in Tables 2, 3, and 4 and Figures 3, 4, and 5. It should be explained that the numbers and Concentrations related to health levels were presented according to the definitions existing in the AQI tables. Tables and figures related to the analysis of results were investigated at three heights of 25 m, 23 m, and ground level. These three levels were selected due to the following reasons:

1. Zero height or ground level: This position was determined in order to find the answer of the question: Does the Concentration of pollutants from the stack reach the ground level? If yes, how much are their pollution and risk for human health? In fact, it can be said that it was a kind of risk assessment.
2. Twenty-three m above ground level: was the height at which the Concentration of Co gas disappeared. In other words, it was the beginning of the height from which Co can influence organisms.
3. Twenty-five m above ground level: was the output level of stack, from which Co and other pollutants of Takestan Steel Factory were emitted. Also, this height had maximum Concentration.

Table 2: Summary of results obtained from modeling emission of pollutants (Co, SO_2, No_2) at stack level (height of 25m)

Pollutant	Good health level (m)	Average health level (m)	Unhealthly health level (m)	Dangerous health level (m)
CO	70	48	36.5	27
SO_2	2020	885	550	370
NO_2	450	310	104	75

Figure 3 was drawn based on the results obtained from Table 2. In this figure, the behavior of Co, SO2, and No2 gases emitted from the stack of Takestan Steel Factory at the height of 5 m (output level of stack) is comparatively shown. Concentrations of this figure were based on the health level index using AQI table, international standard of air quality, and distance to the downstream of the stack. This figure evidently demonstrates that SO2 gas navigated maximum distance at the height of 25 m from the stack downstream and its final board was up to 2020 m from the stack; this issue was due to higher mass flow rate of SO2 emitting from the stack Compared to that of other gasses and also more stability of this heavy gas than two other gasses in air. Co gas has the shortest emission distance, which is one of the most important causes of its lightness Compared to air (or almost the same weight as air). NO2 gas which is heavier than air had an intermediate behavior relative to Co and SO2 gasses due to the negligible mass flow rate of the gas emitted from the stack and Continued up to 450 m distance of the stack downstream. After this distance, it was diluted with air and disappeared.

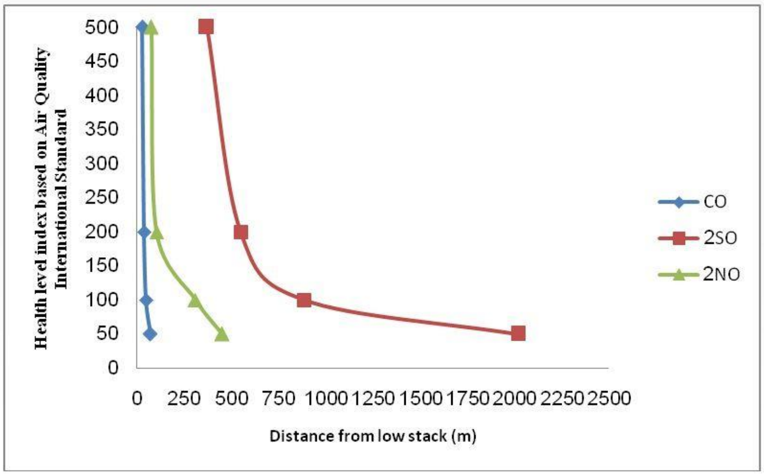

Fig. 3: Results of modeling emission of Co, So2, and NO2 gasses at the stack level related to the atmospheric Conditions in November

Using the obtained results related to modeling the emission of pollutant gases emitted from the stack of Takestan Steel Factory, Table 3 was Completed and then Figure 4 was designed using the information existing in this table. The mentioned figure shows the emission manner of Co, SO2, and NO2 gases emitted from the stack of Takestan Steel Factory at the level of 23 m based on the distance from the stack downstream and AQI health levels. Similar to Figure 4, Co gas was more unstable than SO2 and NO2; also, at the initial distances close to the stack, this gas disappeared and diluted with air. However, two other gasses were more stable than Co and passed more distance owing to high molecular weight. Comparing the distance from the stack at good (with AQI of 50) and dangerous (with AQI of 500) health levels for these gases at the height of 23 m demonstrated that good health level for Co, No2, and So2 gases Continued up to distances of 64, 440, and 2020 m and their dangerous health level was stabilized up to the distance of 20, 62, and 320 m during the factory's performance time.

Table 3: Summary of the results of modeling emission of pollutants (CO, SO2, and NO2) at level of 2 m lower than stack (height of 23 m)

Pollutant	Good health level (m)	Average health level (m)	Unhealthly health level (m)	Dangerous health level (m)
CO	64	40	25	20
SO2	2020	850	520	320
NO2	440	280	100	62

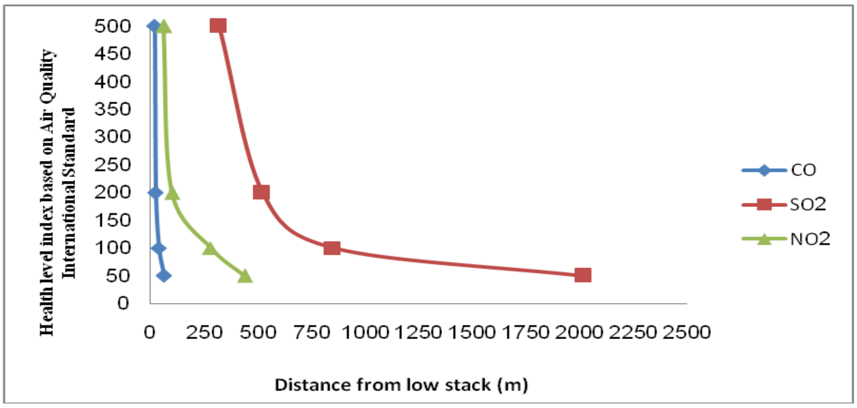

Fig. 4: Results of modeling emission of gasses (Co, So2, and NO2) at distance of 2 m lower than the stack level (at height of 23 m above ground level) related to atmospheric Conditions in November

Table 4 shows the information obtained from modeling the emission of CO gas and two other important gases emitted from the stack of Takestan Steel Company at ground level (height of zero).

Table 4: Summary of the results of modeling emission of pollutants (CO, SO2, and NO2) at ground level (zero height)

Pollutant	Good health level up to distance from the flow downstream (m)	Average health level up to distance from the flow downstream (m)	Unhealthly health level up to distance from the flow downstream (m)	Dangerous health level up to distance from the flow downstream (m)
CO	-	-	-	-
SO2	2020	610	-	-
NO2	-	-	-	-

Figure 5 was drawn using the information from Table 4. As can be observed, this figure evidently shows the point that only SO2 and not the other two (CO and NO2) reached the ground level.

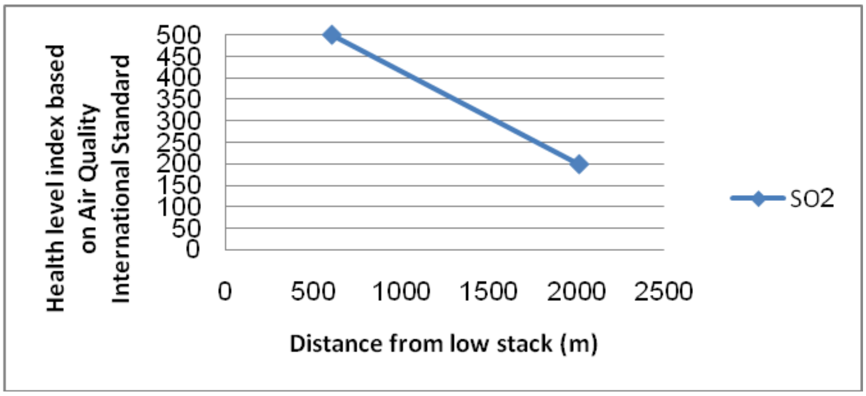

Fig. 5: Results of modeling emission of CO, SO2, and NO2 gases at ground level related to atmospheric Conditions in November

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:

1- Lightness of CO gas (with molecular weight of 28)Compared to air (with molecular weight of 29) or its almost 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.

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