Dispersion Modeling of NO_x and SO_x in Phase 9 and 10 of South Pars Oilfield

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Abstract

The research presented here, represents a segment of a cumulative impact modeling of phases 9 and 10 of South Pars Gas and Petrochemical Complex. It considers point and flare source emissions of sulphur and nitrogen oxides (SO_2 and NO_x respectively), over an about 410 km^2 area. AERMOD View ™ is used to estimate the maximum potential concentration of these pollutants over 1-h, 3-h, 8-h, 24-h, month and annual averaging periods. Results were compared with Air Quality Standards to assess the potential cumulative effects of these pollutants. Lastly Comparison with nearby monitoring data will indicate reasonability of predicted concentrations and usefulness of AERMOD as a tool for approaching the potential cumulative impacts of air pollution from multiple sources. The effects of predicted threshold violations on fragile ecosystems will be discussed.

Keywords: Sulphur and nitrogen oxides. AERMOD. Air quality standards. Cumulative impacts. South Pars

1 Introduction

The importance of air pollution prevention has been increasing in recent years, due to increasing knowledge of pollution sources and their pollution levels. National air quality standards have been established by the United States Clean Air Act to protect man and the environment from damage by air pollutants [6]. Chronic exposure to air pollutants is a worldwide problem. The World Health Organization (WHO) announced that every year approximately 2.7 million deaths can be attributed through air pollution [8].

"Acid Rain," or more precisely acid precipitation, is the word used to describe rainfall that has a pH level of less than 5.6. This form of air pollution is currently a subject of great controversy because of its worldwide environmental damages. For the last ten years, this phenomenon has brought destruction to thousands of lakes and streams in the United States, Canada, and parts of Europe. Acid rain is formed when oxides of nitrogen and sulfite combine with moisture in the atmosphere to make nitric and sulfuric acids. These acids can be carried away far from its origin. The two primary sources of acid rain are sulfur dioxide (SO_2), and oxides of nitrogen (NO_x). Acid rain does not only affect organisms on land, but also affects organisms in aquatic biomes [11].

Possible health effects from Gas and Petrochemical Complexes and related emissions have been a long-standing community concern, particularly when such industrial activities are located near together in a small area such as Assaluyeh [7].

Dispersion is the process of air pollutants emitted from sources such as industrial plants and vehicular traffic dispersing in the ambient atmosphere [10]. An air quality dispersion model is a series of equations that mathematically describe the behavior of pollutants in the air. It provides a cause-effect link between the emissions into the air and the resulting air pollution concentrations. Dispersion models have been used in many different applications, but have traditionally been used for air quality assessments in support of decisions regarding approvals and permits for regulated sources [1]. Dispersion models use a set of scientific equations to describe and simulate the dispersion, transformation and deposition of pollutants emitted into the atmosphere. In addition to the quantity and type of pollutants released into the air, factors such as topography, atmospheric conditions, and the pollutant source location also have a significant effect on air quality [10]. A dispersion model is essentially a computational procedure for predicting concentrations downwind of a pollutant source, based on knowledge of the emissions characteristics (stack exit velocity, plume temperature, stack diameter, etc.), terrain (surface roughness, local topography, nearby buildings) and state of the atmosphere (wind speed, stability, mixing height, etc.) [10]. The model has to be able to predict rates of diffusion based on measurable meteorological variables such as wind speed, atmospheric turbulence, and thermodynamic effects. The algorithms at the core of air pollution models are based upon mathematical equations describing these various phenomena which, when combined with empirical (field) data, can be used to predict concentration distributions downwind of a source [5].

The notion of “cumulative impacts” (or cumulative effects) is gaining acceptance and may eventually replace “traditional” environmental impact assessments around the globe. The US Council on Environmental Quality defines cumulative effects as "the impacts on the environment that result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions" [2]. The cumulative effects concept is, therefore, an acknowledgement that the environmental and socioeconomic effects of individual projects may combine and interact, thereby resulting in structural and functional changes to ecological and social systems that would not necessarily be identified should the assessment focus solely on one project [9].

Currently used dispersion models, such as the AMS/EPA Regulatory Model (AERMOD), process routinely available meteorological observations to construct model inputs. Thus, model estimates of concentrations depend on the availability and quality of meteorological observations, as well as the specification of surface characteristics at the observing site [3]. AERMOD requires steady and horizontally homogeneous hourly surface and upper air meteorological observations [4].

The research presented here, represents a segment of a cumulative impact modeling of phase 9 and 10 of South Pars Gas and Petrochemical Complex. Many different industries and activities are going on in this complex where a huge amount of air pollutant gases will be released to the atmosphere. The common gases will result in cumulative effects which will affect the natural and human environment severely. This study aims to: 1) model dispersion of NOx and SOx in phase 9 and 10 of South Pars oilfield; 2) compare the outputs with Air Quality Standards to estimate the share of these pollutants of the air pollution of the ambient; 3) do the comparison with nearby monitoring data will indicate reasonability of predicted concentrations and usefulness of AERMOD as a tool for approaching the potential cumulative impacts of air pollution from multiple sources; 4) overlay the outputs with landuse map of the study area to realize which populations are affected and which concentrations they are exposed by; 5) overlay the outputs with ecosystems map of the study area to realize which ecosystems are affected and which concentrations they are exposed by. The effects of predicted threshold violations on fragile ecosystems will be discussed.

2 Methods

2-1 Study Area

In this modeling a study area of 410 km2 of South Pars oilfield was chosen. South Pars oilfield was chosen because of (1) the high density of emission sources, (2) community concerns regarding poor air quality in this region, and (3) the proximity to Nayband gulf and national park as fragile ecosystems. . The Iranian South Pars field is the largest discovered offshore gas field in the world, located 100 km offshore in the Persian Gulf. Reservoir fluids are transported to shore via two sea lines to the mainland (Assaluyeh) at a distance of approximately 105 km for further treatment. In this study SO_2 and NO_x sources of 9 and 10 phases of South Pars field was chosen for modeling (Fig. 1).

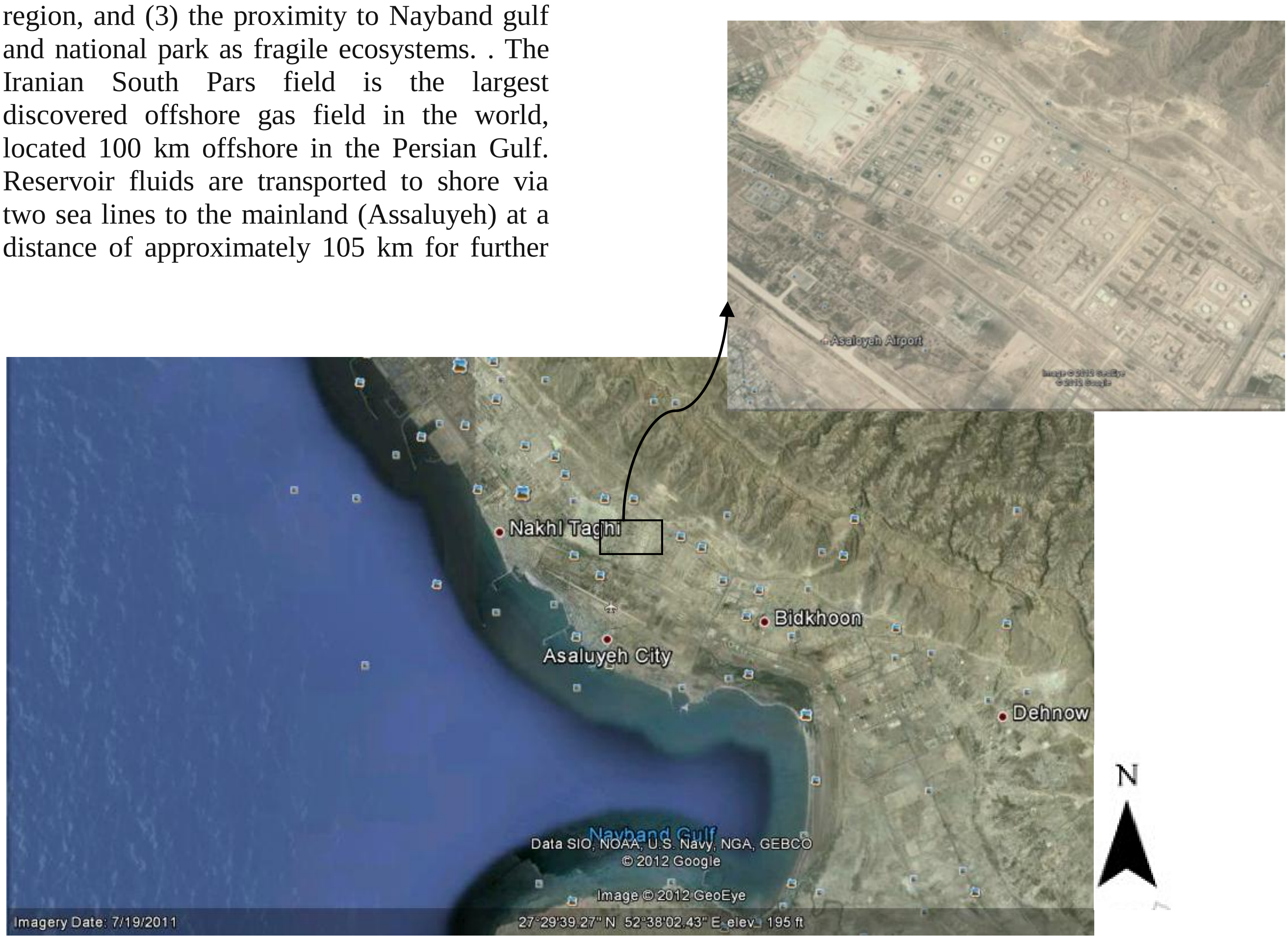

Fig. 1: location of 9 & 10 Phases of South Pars field with Google Earth, 2012

2-2 Dispersion Modeling

Lakes Environmental's AERMOD ViewTM version 7.6.1 was chosen for modeling dispersion of SO2 and NOx. Sulfur dioxide (SO_2) is the criteria pollutant that is the indicator of sulfur oxide concentrations in the ambient air. SO_2 dissolves in water vapor to form acid, and interacts with other gases and particles in the air to form sulfates and other products that can be harmful to people and their environment [13]. SO_2 was chosen as SO_x for modeling because of that. The AERMOD atmospheric dispersion modeling system is an integrated system that includes three modules: [12]

- A steady-state dispersion model designed for short-range (up to 50 kilometers) dispersion of air pollutant emissions from stationary industrial sources.
- A meteorological data preprocessor (AERMET) that accepts surface meteorological data, upper air soundings, and optionally, data from on-site instrument towers. It then calculates atmospheric parameters needed by the dispersion model, such as atmospheric turbulence characteristics, mixing heights, friction velocity, Monin-Obukov length and surface heat flux.

- A terrain preprocessor (AERMAP) whose main purpose is to provide a physical relationship between terrain features and the behavior of air pollution plumes. It generates location and height data for each receptor location. It also provides information that allows the dispersion model to simulate the effects of air flowing over hills or splitting to flow around hills.

The dispersion of pollutants released to the atmosphere is highly dependent on the meteorological conditions into which it is released. Meteorology was supplied by Lakes Environmental in SAMSON format for the Persian Gulf airport and Kangan- Jam station prior to processing with AERMET. The data for the years 2008 and 2009 was used for this purpose. AERMOD is a Gaussian plume model that uses a skewed bi-Gaussian probability density function under convective conditions when vertical plume dispersion is non-Gaussian [16]. More information on AERMOD and AERMOD View™ 7.6.1 including algorithms and background science can be obtained from the US-EPA (http://www.epa.gov/scram001/dispersion_prefrec.htm) and from Lakes Environmental (http://www.weblakes.com).

AERMAP is a terrain data preprocessor that incorporates complex terrain using USGS Digital Elevation Data (http://gdex.cr.usgs.gov/gdex/).

In this study rural and elevated options were chosen for the uniform 40×40 Cartesian grid with 500m spacing and with a center reference point (UTM Zone 39 WGS 1984, North: 3042640 m & East: 661529 m).

The emissions to air consider SO_2 and NO_X. As all the combustion units burn sweet fuel gas with less than 2 ppm of sulphur containing compounds, the primary source of SO_2 is from the sulphur recovery units during normal operation. The major NO_X emission sources include gas turbines and steam boilers during normal operation [15]. Stacks and flares with emission rates over than 1g/s were chosen for modeling. Therefore 4 sources (2 stacks and 2 flares) were used for SO_2 dispersion modeling and 12 sources (12 stacks) were used for NO_X dispersion modeling. Stack and flare parameters assigned to point and flare sources used in AERMOD View are given in table 1.

Table 1: Stack and Flare parameters used in AERMOD View

Sources	Stack Height m	Flue Gas Temp. °K	Flue Gas Velocity M/s	SO2 G/s	NOX G/s
Steam Boiler	43	458	12.24	-	7
Steam Boiler	43	458	12.24	-	7
Steam Boiler	43	458	12.24	-	7
Steam Boiler	43	458	12.24	-	7
Steam Boiler	43	458	12.24	-	7
Steam Boiler	43	458	12.24	-	7
Compressor gas turbine	30	776	10.99	-	22.67
Compressor gas turbine	30	776	10.99	-	22.67
Compressor gas turbine	30	776	10.99	-	22.67
Compressor gas turbine	30	776	10.99	-	22.67
SRU tail gas incinerator (SRU Trip Case)	95	625	5.43	330.3	4.8
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LP Flare (Normal)	25	317	1.5	1.36	-
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3 Results

3-1 Predicted Concentrations

This study considers point and flare source emissions of sulphur and nitrogen oxides (SO_2 and NO_x respectively), over an about 410 km^2 area. The time period from 11/1/2008 to 10/31/2009 was chosen for modeling.

AERMOD output was averaged over 1-h, 3-h, 8-h, 24-h, monthly and annual periods for both SO_2 and NO_x. Maximum predicted value concentrations for specified AERMOD averaging times occurred in mountains near emission sources (Fig. 3). These values are given in table 2 and Fig. 2a–d.

Table 2 AERMOD View predicted maximum concentrations over averaging times

Concentration (µg/ m3)

Pollutant	1 h	3 h	8 h	24 h	Month	Annual
SO_2	9732.11	3878.45	1856.29	846.37	157.99	114.82
NO_X	1789.32	826.89	408.97	194.24	82.02	68.43

Predicted maximum concentrations were exceeded all the chosen SO_2 limits (Table 3 and 4). Predicted maximum NO_x concentrations exceeded standards in 24-h average time but it did not exceed in maximum annual average time (Table 3 and 4).

Table 3 Project Air Quality Standards for South Pars [15]
Standards during normal operation

Parameter	Project Standards (µg/m³)	Iranian Petroleum Standards (1) (µg/m³)	Averaging period
Sulphur Dioxide (SO2)	50	80	Annual Mean
	125(3)	365(2)	24 hour average
Oxides of Nitrogen NOx (such as NO2)	40	100	Annual Mean
	150	-	24 hour average

Remark:

(1) Iranian Petroleum Standard IPS –E-SF-860

(2) Not to be exceeded more than once a year

(3) 98th percentile of all daily values taken throughout the year; should not be exceeded more than 7 days a year

Table 4 National and Wyoming Air Quality Standards for Criteria Pollutants [14]

Pollutant	Averaging Time	NAAQS (mg/m3)	WAAQS (mg/m3)
Nitrogen dioxide (NO2)	Annual	100	100
Sulfur dioxide (SO2)	3 hour	1300	695
	24 hour	365	260
	Annual	80	60

4 Discussion

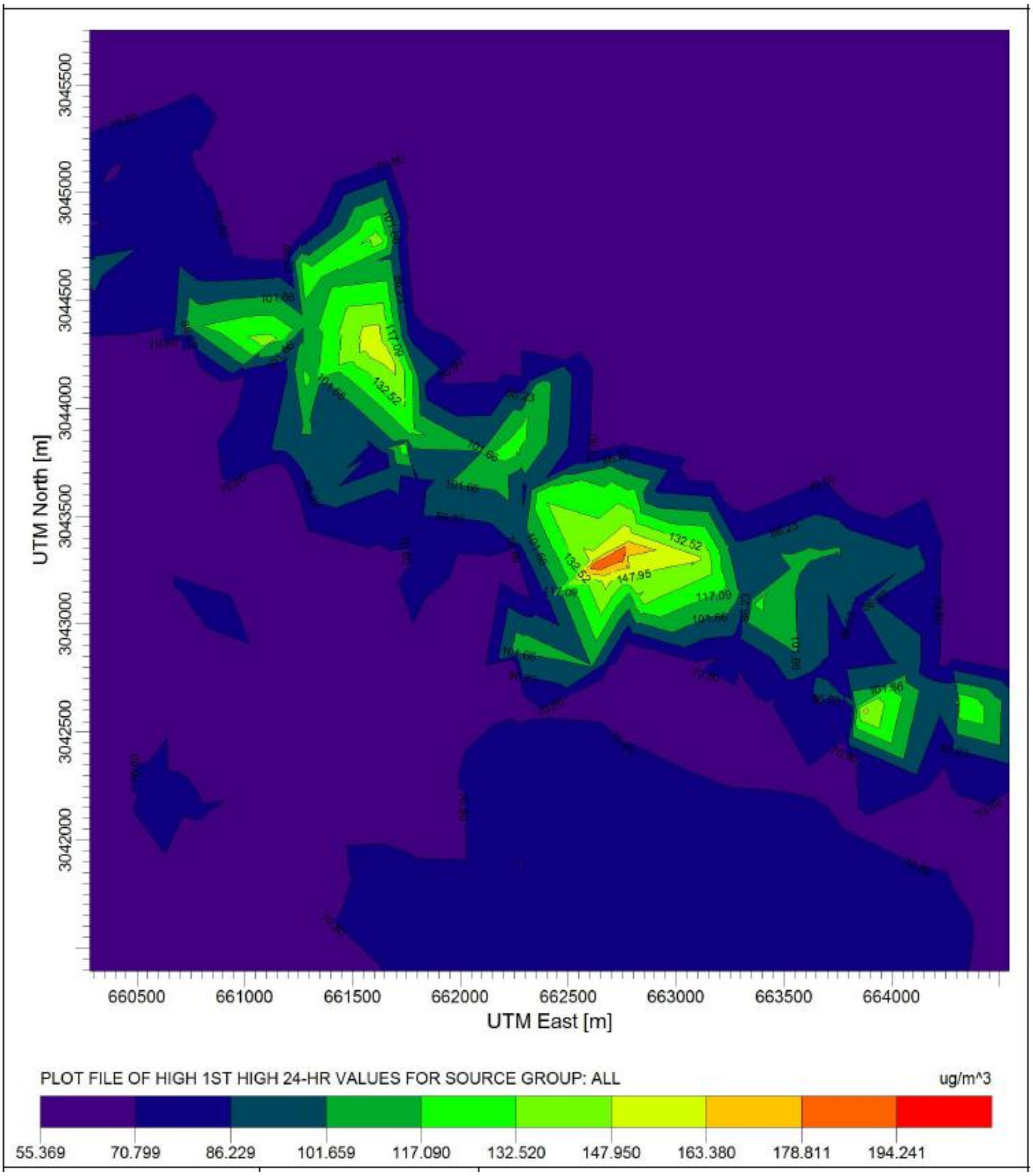
There are 28 phases South Pars Gas Field. Although, we are sure that the general concentrations of studied gases are the commutation of all the emission sources in the studied area, but we modeled the concentration of the gases as a pilot study for two phases. Background concentrations of SO_2 and NO_x were taken for this purpose. Based on the previous studies, background concentration values used for SO_2 and NO_x were 22 and 55 ppb respectively.

However, the purpose of this study was to apply AERMOD software as a tool for approaching the potential cumulative impacts of air pollution from multiple sources in phases 9 and 10 of South Pars Gas Field.

The results indicate that we have the most dispersion of both gases in the Northwest of the studied area on the mountains (As shown in Fig. 3). So, we conclude that it might be as the effect of the wind direction which is coming from the southeast.

In short average times (1-h, 3-h, 8-h and 24-h) maximum predicted concentrations were exceeded the standards by both SO_2 and NO_x. It was represent the potential short term impacts of these pollutants on human healthy and fragile ecosystems. The maximum predicted concentration in annual average time of SO_2 was exceeded standards and it can be concluded the potential long term impacts of SO_2 maximum concentrations in the long periods of time in this study area. But maximum predicted concentration in annual average time of NOx did not exceed the standards, it can be concluded that maximum NOx concentrations in long periods of time cannot have considerable potential impacts.

(a)


3045500
3045000
3044500
3044000
3043500
3043000
3042500
3042000
UTM North [m]
660500
661000
661500
662000
662500
663000
663500
664000
UTM East [m]
PLOT FILE OF HIGH 1ST HIGH 24-HR VALUES FOR SOURCE GROUP: ALL
ug/m^3
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86.229
101.659
117.090
132.520
147.950
163.380
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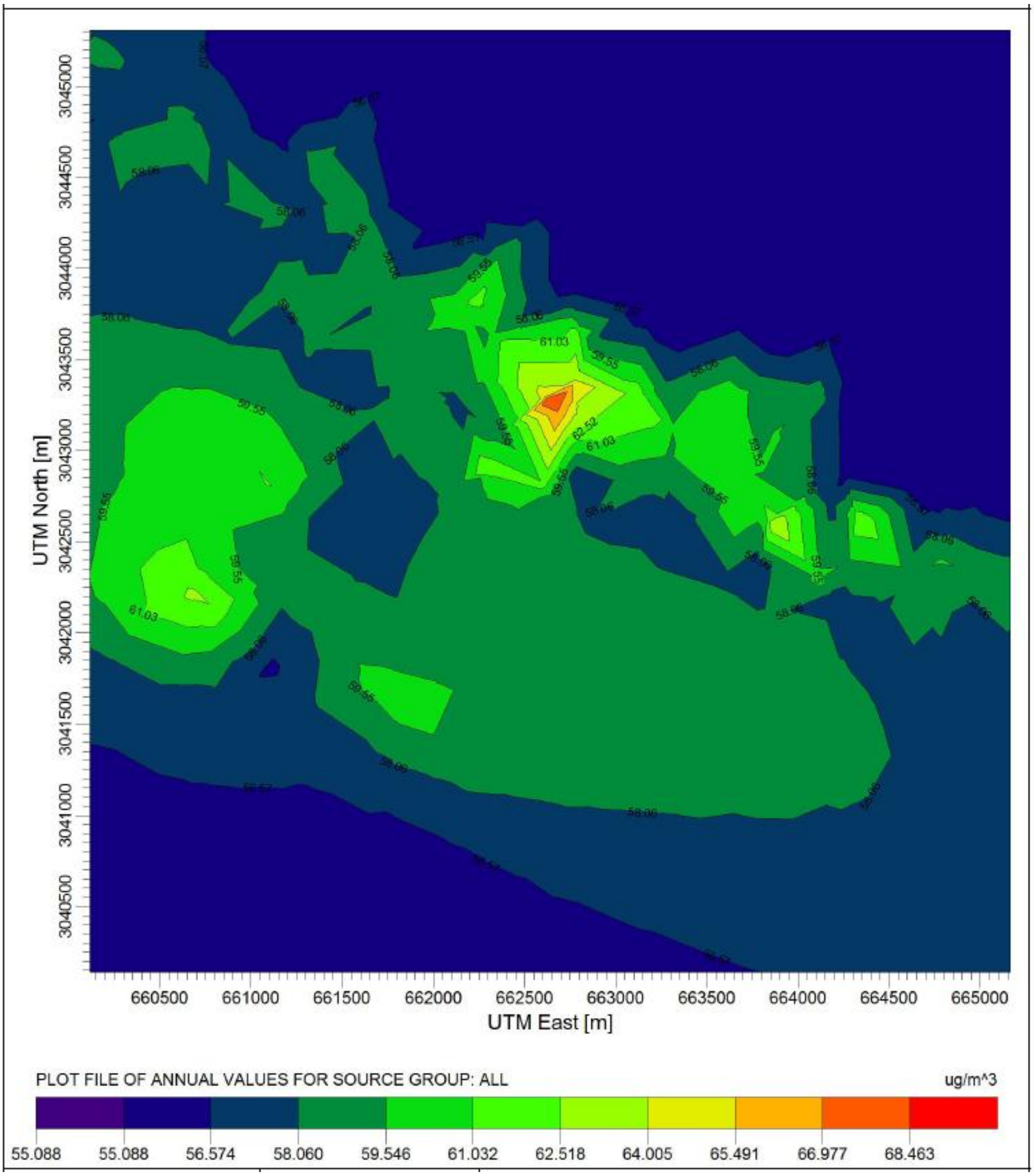
194.241

(b)


UTM North [m]
UTM East [m]
PLOT FILE OF ANNUAL VALUES FOR SOURCE GROUP: ALL
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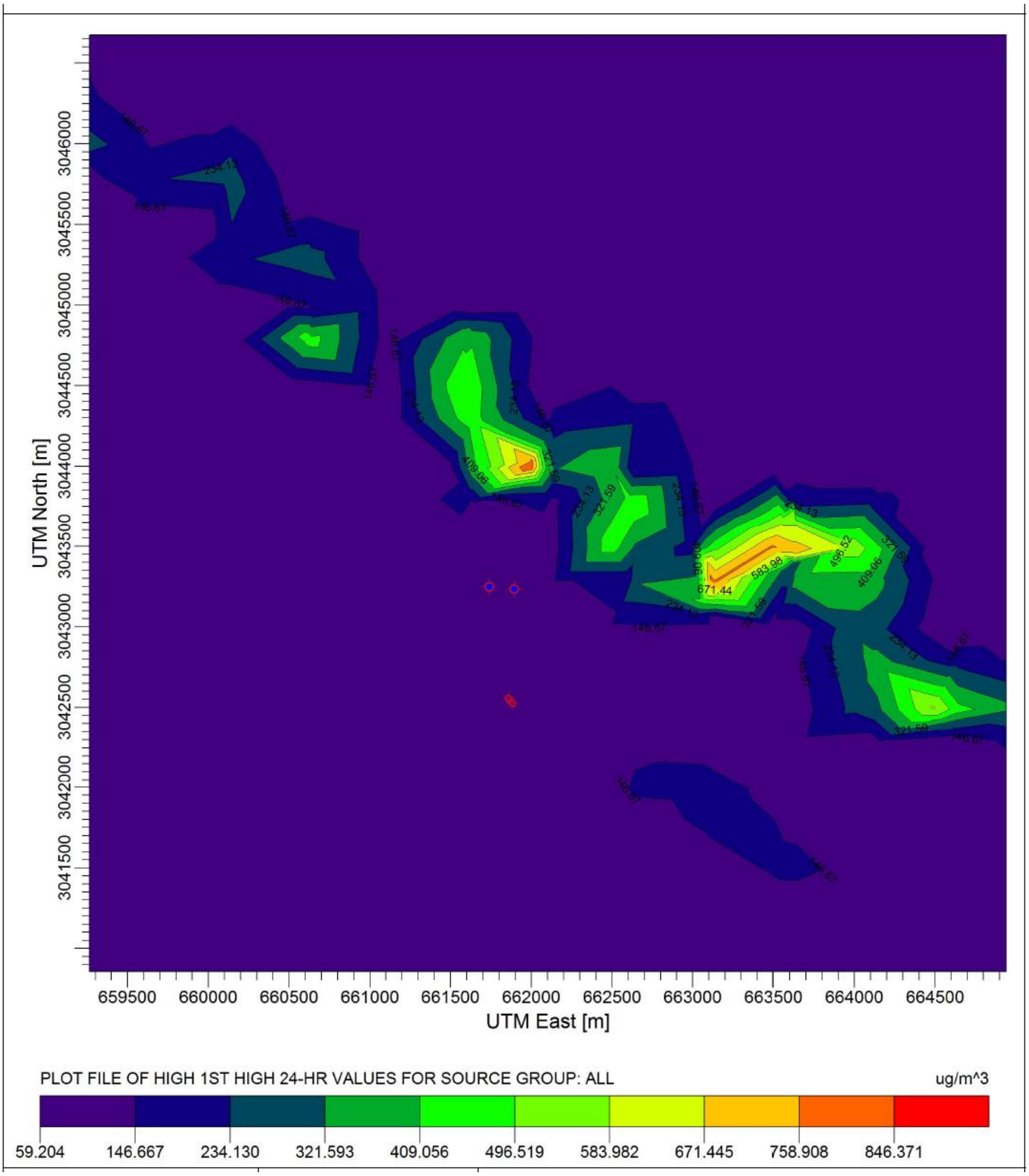
61.032
62.518
64.005
65.491
66.977
68.463

(c)


UTM North [m]
UTM East [m]
PLOT FILE OF HIGH 1ST HIGH 24-HR VALUES FOR SOURCE GROUP: ALL
ug/m^3
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234.130
321.593
409.056
496.519
583.982
671.445
758.908
846.371

(d)

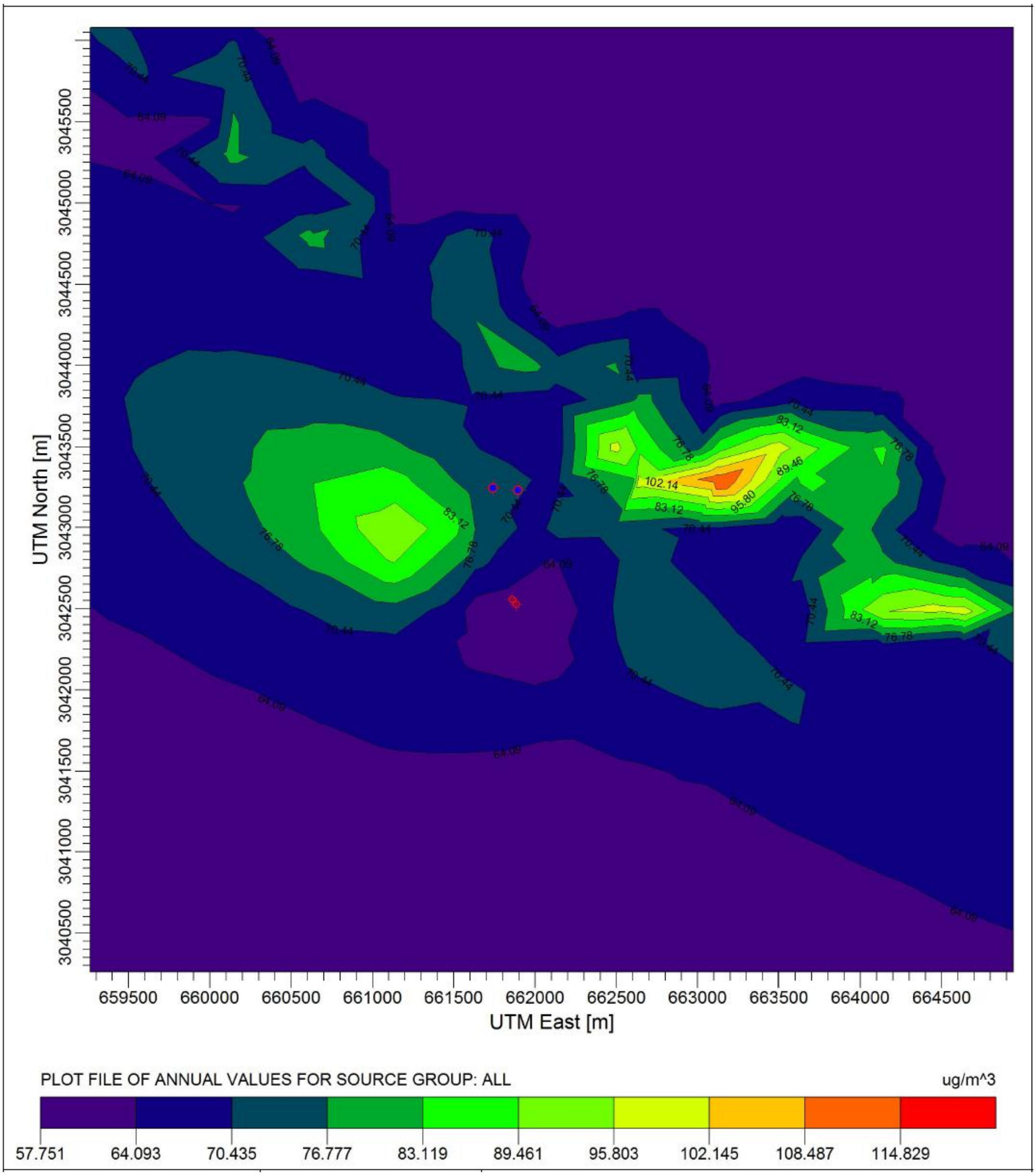

Fig. 2: Maximum predicted value concentrations for specified AERMOD averaging times (24h- Annual) for NOx (a- b) and SO2 (c- d)

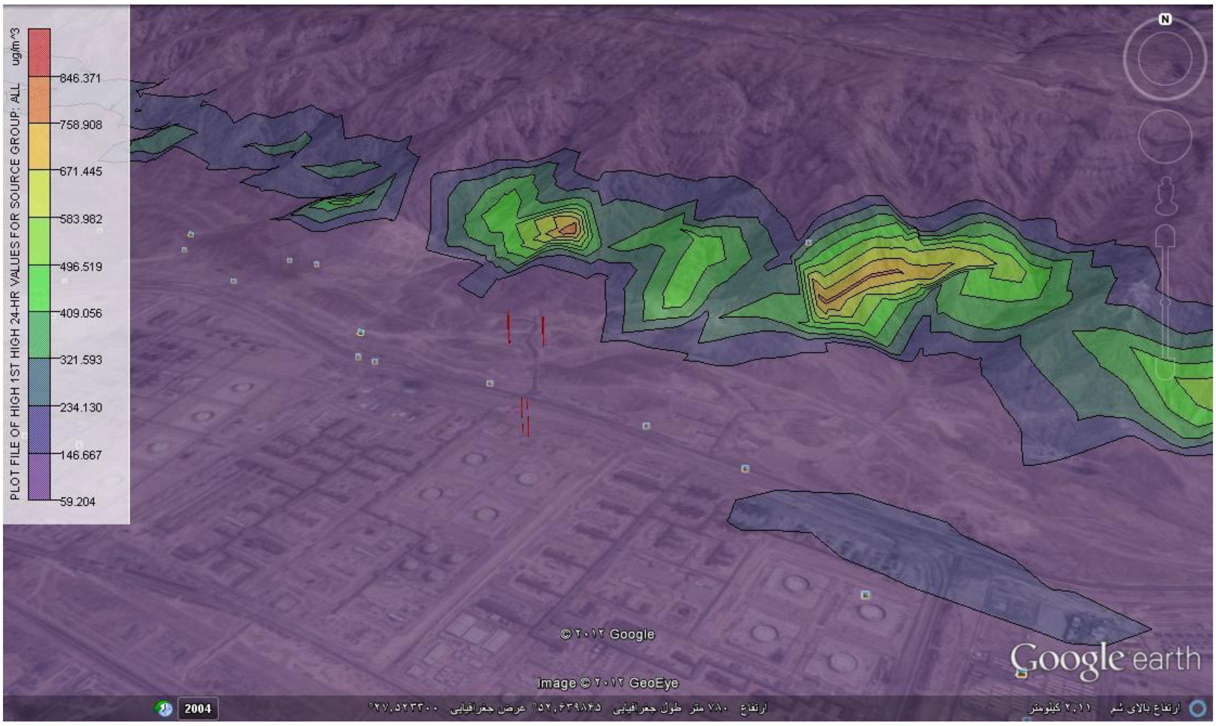

Fig. 3: Maximum concentration contours of SO2 over 24 h average time overlaid on Google Earth

5 Conclusions

The isolation of facilities and events for current atmospheric release permits (and traditional environmental impacts assessments) ignores the potential cumulative impacts of multiple emission sources (or activities) in shared space and time. While individual plants and small emission sources may appear benign, when considered cumulatively, even over a relatively small study area, their plumes have the potential to intersect and exceedances of ambient air concentration standards for SO_2 and NO_x are likely to occur. Episodically high concentrations occur under conditions of a stable boundary layer with light winds and little convective or turbulent mixing.

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