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EXPERIMENTAL ANALYSIS AND STUDY OF POLLUTION FOOTPRINT IN BUCHAREST METROPOLITAN AREA

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Analiza experimentală a surselor de poluare şi studiul amprentei poluării în zona metropolitană Bucureşti pentru cele patru anotimpuri reprezintă scopul acestei lucrări. Studiul este realizat pentru poluanții NOx şi SO2 proveniți de la centralele termoelectrice, datele de intrare fiind obținute de la stațiilor automate de monitorizare a calității aerului. Informațiile stocate într-o bază de date Acces sunt prelucrate pe baza modelului gaussian de dispersie a calității aerului OML (Operational Local Model). Programele elaborate permit atât obținerea dispersiei concentrațiilor provenite de la fiecare sursă în parte cât şi concentrația de poluant într-un anumit punct geografic, datorită tuturor surselor poluatoare.

Experimental analysis of pollution sources and pollution footprint study in the metropolitan area of Bucharest for four seasons is the goal of this work. The study is conducted for NOx and SO_2 pollutants coming from power plants, the input data is obtained from automatic monitoring stations for air quality. The information stored in an Access database is processed based on the Gaussian model dispersion air quality OML (Local Operational Model). The programs developed allow the dispersion to obtain concentrations from each individual source and pollutant concentration in a certain geographical point.

Keywords: pollution, modelling, automatic monitoring stations, power plants

1. Introduction

Air pollution, from antiquity, is considered an essential feature for society. Since fire was first discovered, first anthropogenic sources of pollution started to appear. From Bronze and Iron Age, metals smelting and refining had generated new sources for pollution. The main causes of pollution in that period were caused by: heating, cooking, metallurgy, tannery and pottery. In antiquity, with population concentration in urban areas increasing first pollution effects started to appear (difficulty in breathing air from Rome- due to stack) [1].

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Industrial revolution represents the threshold from which the level of pollution grew fast as a result of increased energy needed for the production of steam power engine. In the 19th century, coal became the main used fuel causing a significant increase in smoke and ash released into atmosphere [2].

First air quality monitoring stations of large capabilities were introduced in USA at Salt Lake City (1926), New York (1937) and in England at Leicester (1939). After 1970, air pollution treatment stations evolved into a global environmental approach in all industrialized countries.

Respecting the criteria imposed by the European Union, in Romania were established 11 stations to assess and manage air quality in: Bucharest, Craiova, Pitesti, Ploiesti, Constanta, Braila – Galati, Iasi, Baia Mare, Cluj Napoca, Timisoara and Brasov. According to MO. 745/2002A, other 8 areas for managing air quality were established [3].

The purpose of this paper is the experimental analysis and pollution footprint study in the metropolitan area of Bucharest for all year. The study was conducted for NO_x and SO_2 pollutants coming from power plants in Bucharest (Progresu, Sud, Titan, Vest and Grozavesti). Gaussian dispersion model for air quality OML (Local Operational Model) was used and, for the environmental impact of fossil fuel burning by transboundary pollution with SO_2, same model was used.

Computer programs allow prediction to be made regarding the amount of pollutants at any point in the analysed geographical area. This is a useful tool for taking (appropriate) technical measures to decrease pollution in a certain area where there was no previous knowledge of the quantity of pollutants in the atmosphere.

2. Measurement methods and data processing

Measurement methods used for pollution monitoring are grouped into two categories: extractive method (extraction of gas samples from stack) and in-situ method (different from extractive method by the lack of sampling system and sample gas conditioning) [4]. Example:

- SO_2 measuring method (UV analyser – excited fluorescence) – This method is very sensitive and it is a specific method for analysing the SO_2 pollutant in ambient air and stack;
- NO_x and O_3 measuring method – this method was developed for the measurement of NO and ozone using specific agents that react with ozone to produce NO or light (chemiluminescence);
- Methods for measuring concentrations of particulate matter in the air - gravimetric method.

Measurement methods are implemented in data acquisition systems. Most of them are automated allowing information collection, transmission, development of databases and information processing for population information [5]. For example, to analyse the variation in temperature and in atmospheric pressure, a database was realised – Fig. 1 and Fig. 2, the results are represented as graphs - Fig. 4 - for a year (365 days).

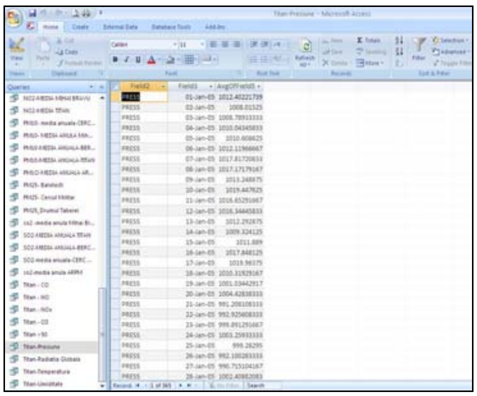


Fig. 1. Database for pressure.

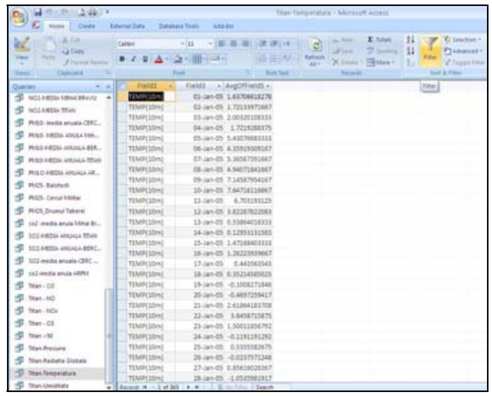


Fig. 2. Database for temperature.

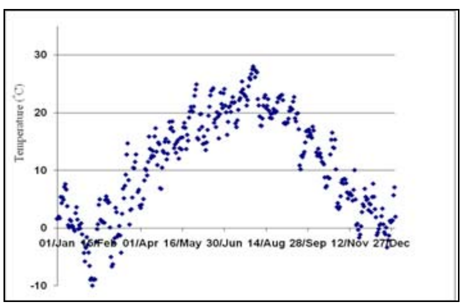


Fig. 3. Variation of temperature.

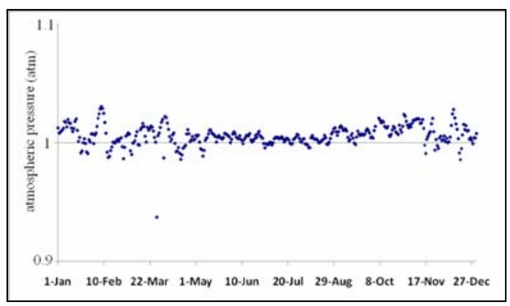


Fig. 4. Variation of atmospheric pressure.

Data regarding air quality in Bucharest (measurement in pollutants: SO_2, NOx, CO, O_3, benzene, PM_{10}, $PM_{2,5}$ and lead) are provided in real time and came from the eight automatic stations (Fig. 5): background station – Balotesti; suburban station – Magurele; urban station – Lacul Morii (EPA Bucharest); two traffic stations – Mihai Bravu and Cercul Militar; three industrial stations– Drumul Taberei, Titan and Berceni.

The Access Database Base structure is represented in Fig. 6. Seasonal concentration of pollutant was determined and all the data resulting from processed data was put in agreed format for Gaussian dispersion model OML (Operational Local Model). The OML model, a modern Gaussian model intended to be used for distances up to about 20 km from source is a two dimensional model [6]. At present time, this model appears to be the only type capable of dealing with buoyant sources and with a wide range of stability conditions [7].

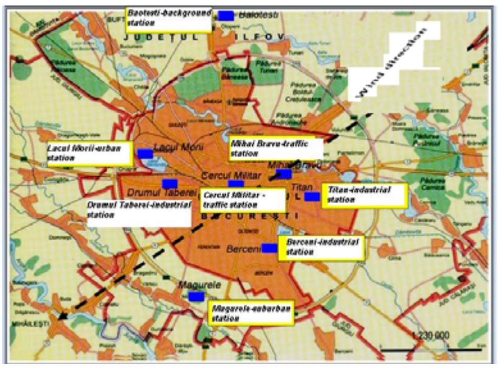


Fig. 5. Automatic stations in Bucharest.

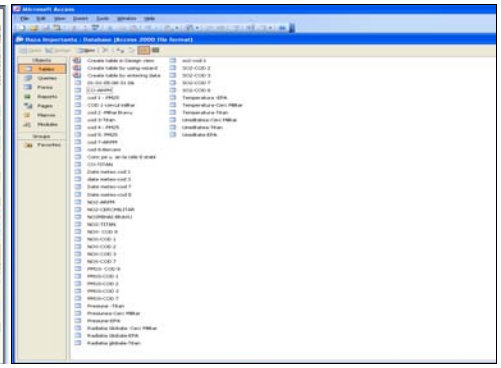


Fig. 6. Import window tables for each station.

Ground concentrations are represented by the gaussian form of plume rise:

$$\langle c(x,y,0)\rangle = \frac{Q}{\pi \bar{u}\,\sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left[\exp\left(-\frac{{h_{ef}}^2}{2\sigma_z^2}\right)\right] \tag{1}$$

where: Q - emission; h_{ef}- effective height; $\bar{u}$ - average speed; σ_z and σ_y - correlation coefficients and c – pollutant concentration.

Dispersion parameters are calculated by combining all the contributions from the turbulence associated with each physical phenomenon that it is generated. As a general rule, every given σ (σ_y or σ_z) can be decomposed in the following way:

$$\sigma^2 = \sigma_{turb}^2 + \sigma_{intern}^2 + \sigma_{building}^2 \tag{2}$$

where: σ_{turb} - dispersion due to atmospheric turbulence; σ_{intern} - dispersion phenomenon arising from ascending mixing pollutant with ambient air; $\sigma_{building}$ - dispersion due to the presence of buildings in close proximity of the pollutant emission source. On the same principle of decomposition based on statistical theory of turbulence due to atmospheric diffusion, the term can be written:

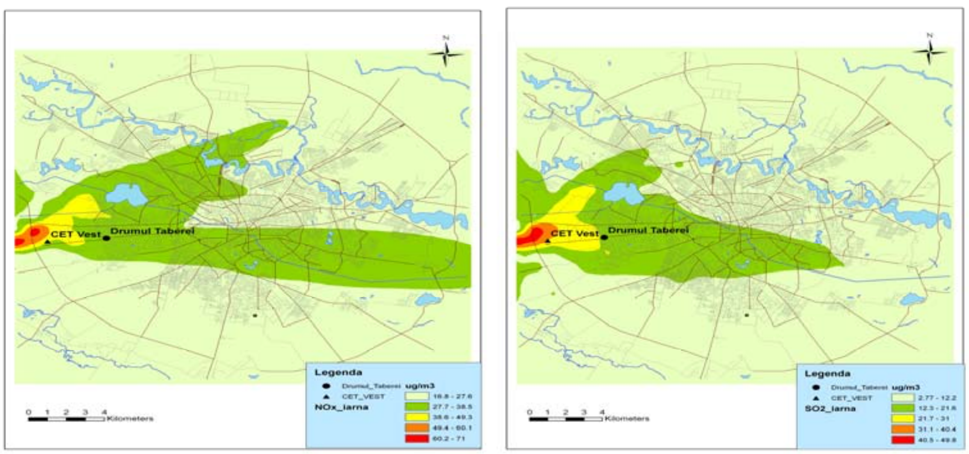
$$\sigma_{turb}^2 = \sigma_{mech}^2 + \sigma_{conv}^2 \tag{3}$$

where σ_{mech}, σ_{conv} dispersion parameters that are associated with mechanical and convective processes that generate air turbulence.

In the model considering the dispersion of pollutants vertical and horizontal and cannot take account of the pollutant plume.

The main innovation in the OML model is the way in which the dispersion parameters σ_y and σ_z are determined, directly related to the basic physical parameters describing the turbulent state of the atmospheric boundary layer [8].

The computer program developed was applied to data from automatic monitoring stations in the territory, for each pollutant separately. Fig. 7 presents the results obtained for the change in NO_x and SO_2 concentrations in winter, from Vest Power Plant.



a) NOx b) SO2

Fig. 7. Maps of Bucharest showing concentration of NO_x and SO_2 emissions during winter season. Power Plant Vest

By calculating changes in concentrations of NO_x and SO_2 emissions from all listed pollution sources, maps, as those in Fig. 7, were drawn.

3. Footprint of atmospheric pollution in Bucharest metropolitan area

The problem was to obtain a method for using the results in chaging concentrations of contaminants from each pollution source and to determine the overall concentration of pollutants in a defined geographical point. The software was adapted to the input data (emissions from industrial sources, calculated by the authors) and, after running Gaussian dispersion model OML, the dispersion concentrations of pollutants (SO_2 and NOx) from the power plants was mapped. The dispersion of concentrations of pollutants was mapped using the interpolation methode from ArcGIS software. ArcGIS is a geographical information systems witch gives you the power to manage and integrate your data, perform advanced analysis, model and automate operational processes, and display your results on professional-quality maps. Results are presented for all four seasons: winter, spring, summer and autumn and taken into account the wind direction for Bucharest (Fig. 8).

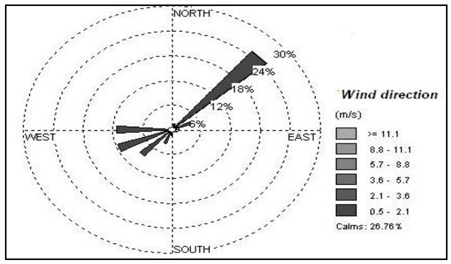


Fig. 8. Bucharest Wind Rose.

The values of concentrations were compared with the limit values for NOx (30 μg/m^3) and for SO_2 (20 μg/m^3) [10]. And, afterwards, the results were obtained after data processing.

3.1. Pollution footprint for Grozavesti and Progresu power plants

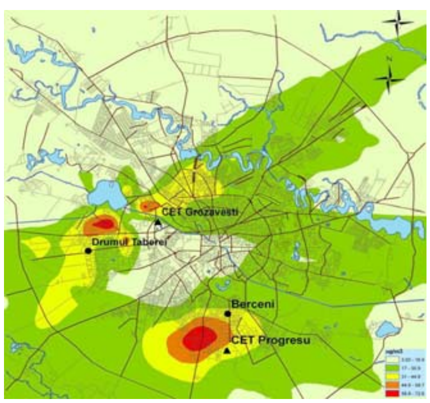


Fig. 9. NOx - Winter season.

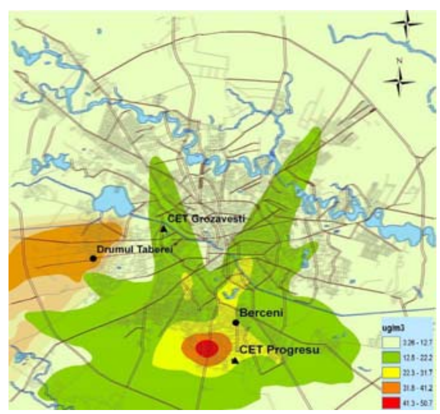


Fig. 10. NOx - Spring season.

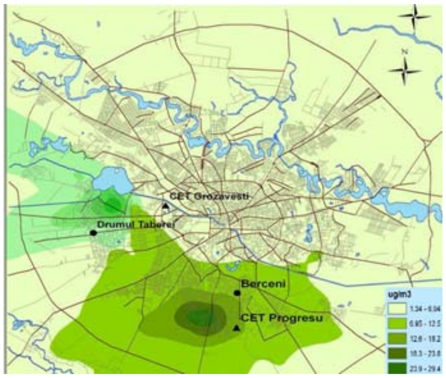


Fig. 11. NOx - Summer season.

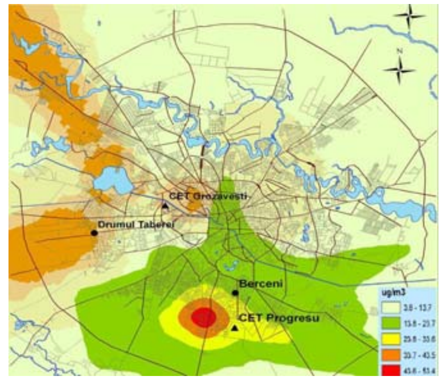


Fig. 12. NOx - Autumn season.

Maps of Bucharest showing concentration of NO_x emissions from power plants Grozavesti and Progresu during all seasons

Variations in concentrations for pollutant NO_x in Bucharest maps for all the four seasons, are represented in Figs. 9 to 12. Dispersion analysis for the NO_x concentrations can be observed from winter to spring and autumn. The highest impact had the oldest power plant- Grozavesti.

Variations in concentrations for SO_2 in Bucharest, are presented in Figs. 13 to 16. The pollution analysis for all four seasons shows that it has an increased impact in the southern part. This is because of meteorological conditions, changing in wind directions and wind speed and thermal inversions that often takes place during spring. Progresu power plant has a real impact only in the south of the city. In case of pollution with SO_2, the plume raises from the border of the city to the neighbour (satellite) towns.

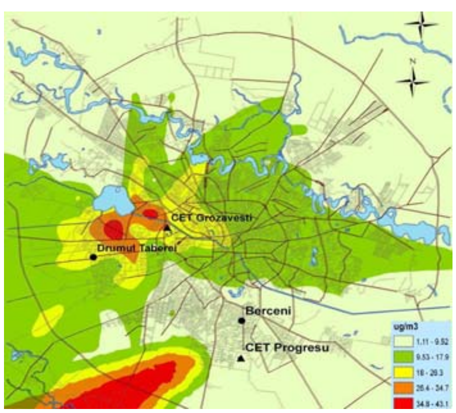


Fig. 13. SO_2 -Winter season.

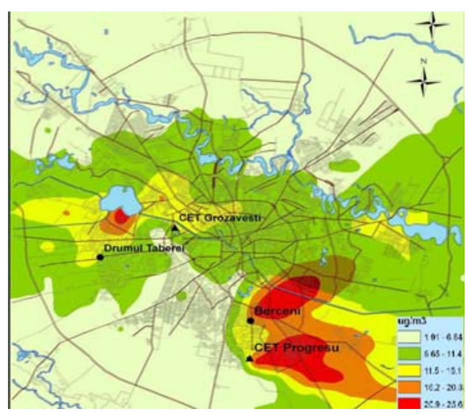


Fig. 14. SO_2 - Spring season.

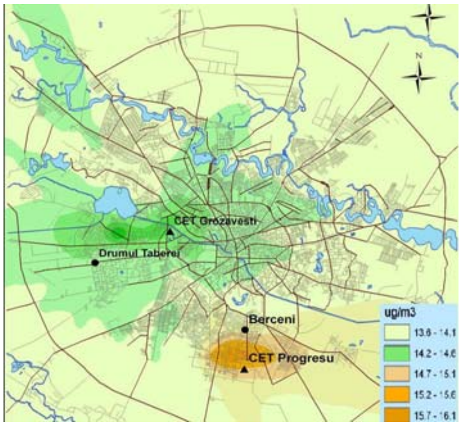


Fig. 15. SO_2 -Summer season.

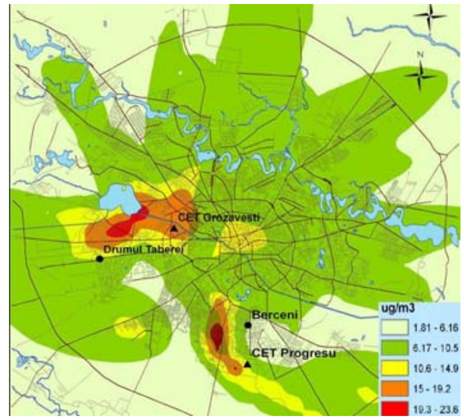


Fig. 16. SO_2 -Autumn season.

Maps of Bucharest showing concentration of SO_2 emissions from power plants Grozavesti and Progresu during all seasons

3.2. Pollution footprint for power plants Vest, Sud and Titan

Variations in concentrations for NO_x pollutant on Bucharest maps for all four seasons, are presented in Figs. 17 to 20 and for pollutant SO_2, in this case, are represented in Figs. 21 to 24. Footprint analysis for the pollution, in this case, can be observed. Pollution level for this part of the city, except autumn, can be observed covering the entire area.

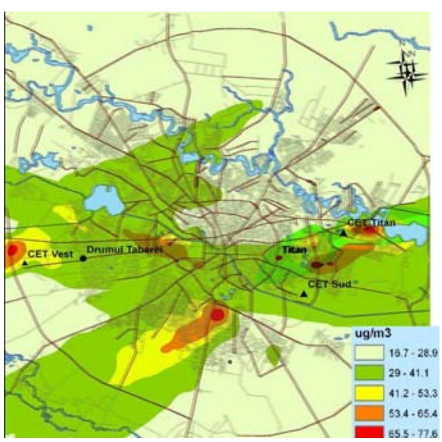


Fig. 17. NOx - Winter season.

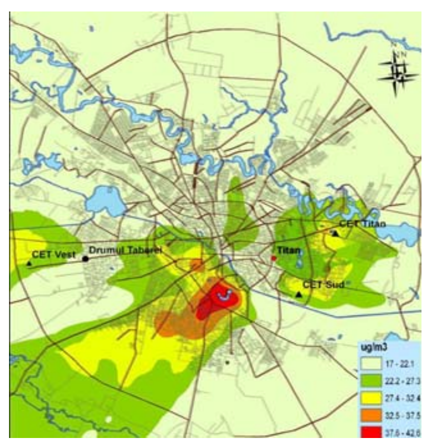


Fig. 18. NOx - Spring season.

Fig. 19. NOx - Summer season.

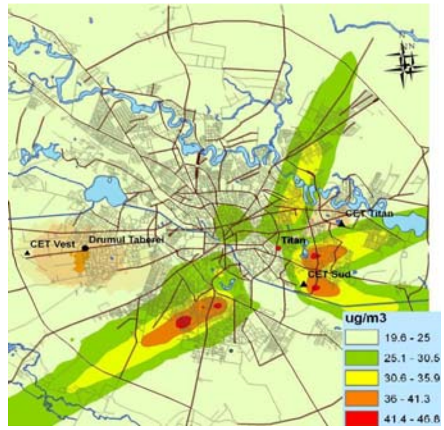


Fig. 20. NOx - Autumn season.

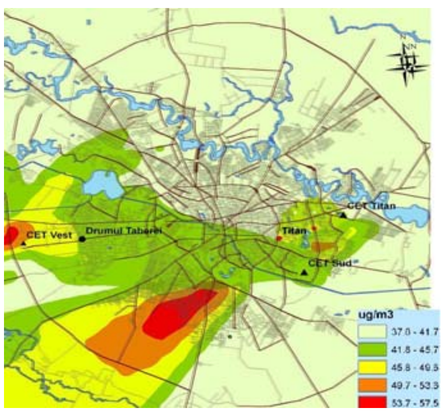


Fig. 21. SO_2 -Winter season.

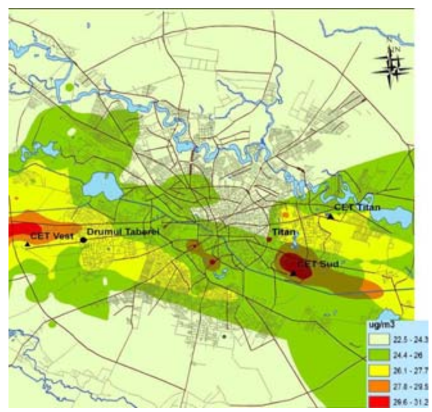


Fig. 22. SO_2 - Spring season.

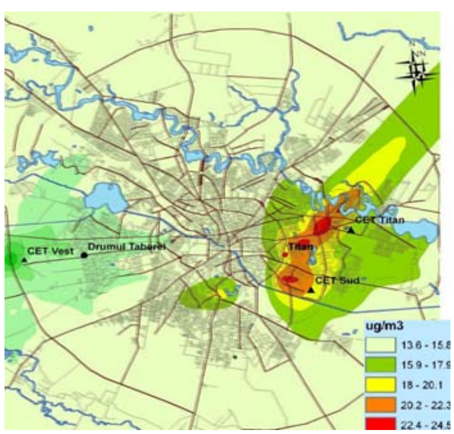


Fig. 23. SO_2 -Summer season.

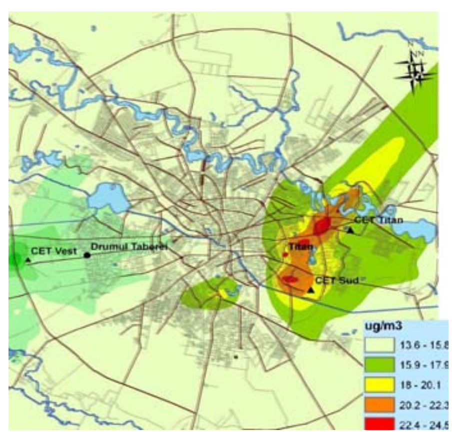


Fig. 24. SO_2 -Autumn season.

Maps of Bucharest showing concentration of SO_2 and NO_x emissions from power plants Vest, Sud and Titan for all seasons

4. Conclusions

This paper presents an experimental study about the sources of atmospheric pollution in the metropolitan area of Bucharest; Observations are made based on computer programs developed by the authors and a prediction in concentration of polluting substance is made in a clearly defined geographical point.

An Access database was developed to obtain the needed information provided by automatic monitoring stations from Bucharest area, such as: meteorological parameters (temperature, pressure) and the concentrations in the atmosphere of NOx and SO_2 pollutants.

For the analysis of pollutants a Gaussian dispersion model was used - OML (Local Operational Model) and important results were obtained regarding the sources of pollution represented by five power plants.

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