ISSN 2333-9179 (Print), ISSN 2333-9187 (Online)

International Journal of Mechanical Engineering and Automation

Volume 2, Number 1, January 2015

www.ethanpublishing.com

Aims and Scope

International Journal of Mechanical Engineering and Automation, a monthly internationally peer-reviewed journal, seeks to promote rapid communication and exchange particularly in practical application of up-to-date technology in realm of mechanical engineering, automation technology and other relevant fields. And articles interpreting successful policies, programs or cases are also welcome.

Members of Editorial Board (in alphabetical order)

Ernest Nazaryan (Yerevan State Universitet, Republic of Armenia), Filip Ilie (Polytechnic University of Bucharest, Romania), Isak Karabegović (University of Bihac, Bosnia and Herzegovina), Kovalevskyy Sergiy (Donbas State Engineering Academy, Ukraine), Lyudmila Ryabicheva (Volodymyr Dahl East Ukrainian National University, Ukraine), Predrag Dasic (High Technical Mechanical School of Professional Studies in Trstenik, Serbia), Satoru Okamoto (Shimane University, Japan), Sergio Baragetti (Università degli Studi di Bergamo, Italy), Shanti Bhushan (Mississippi State University, USA), Simeon Panev (University of Chemical Technology and Metallurgy-Sofia, Bulgaria), Soo Whan Ahn (Gyeongsang National University, Korea), Stefano Mariani (Politecnico di Milano, Italy), Xinqian Zheng (Tsinghua University, China), Zied Driss (University of Sfax, Tunisia)

Manuscript Submission

Manuscripts and correspondence are invited for publication. You can submit your papers via web submission, or E-mail to IJMEA@ethanpublishing.com. Submission guidelines and web submission system are available at http://www.ethanpublishing.com.

Subscription Information

Price (per year)
Print: $300; Online: $180
Print and Online: $400

Editorial Office

1902 Merced Ave, South El Monte, CA 91733, USA
Ethan Publishing Company
E-mail: info@ethanpublishing.com

Copyright©2015 by Ethan Publishing Company and individual contributors. All rights reserved. Ethan Publishing Company holds the exclusive copyright of all the contents of this journal. In accordance with the international convention, no part of this journal may be reproduced or transmitted by any media or publishing organs (including various websites) without the written permission of the copyright holder. Otherwise, any conduct would be considered as the violation of the copyright. The contents of this journal are available for any citation. However, all the citations should be clearly indicated with the title of this journal, serial numbers and the names of the authors.

www.ethanpublishing.com

International Journal of Mechanical Engineering and Automation

Volume 2, Number 1, January 2015

Contents

Int. J. Mech. Eng. Autom.
Volume 2, Number 1, 2015, pp. 47-53
Received: October 26, 2014; Published: January 25, 2015

International Journal of
Mechanical Engineering
and Automation

Dispersion Model for Regulatory Purposes: Development and Evaluation

Igor Andreevski[1], Gligor Kanevče[2], Ljubica Kanevče[1] and Sevde Stavreva[1]

1. Department of Mechanical Engineering, Faculty of Technical Sciences, University St. Clement of Ohridski, Bitola 7000, Macedonia

2. Macedonian Academy of Science and Art, Skopje 1000, Macedonia

Corresponding author: Igor Andreevski (igor.andreevski@uklo.edu.mk)

Abstract: Today, we are witnessing increased environmental pollution, including ambient air, on local, regional and global scale. The existing air pollution from industrial facilities or thermo plants, as well as potential pollution scenarios in normal or accident conditions can be simulated in a relatively simple and efficient way using computer dispersion models. Dispersion models used today are different in many aspects. In this paper, the dispersion models categories suitable for application in conditions and in solving problems of local air pollution in Macedonia are considered. Also regulatory model—MADAM (MAcedonian Dispersion Atmospheric Model) development is presented. MADAM has been developed by the research group from Faculty of Technical Sciences, Bitola in the past fifteen years. It belongs to the well known Gaussian models group, but some modifications have been made in recent years, implementing results from inverse estimations in order to improve its overall performances. The paper points out benefits gained from inverse calculations and models algorithm improvements seen thru better model evaluation results using BOOT procedure.

Keywords: Air pollution, regulatory dispersion model, dispersion simulation, MADAM (Macedonian dispersion atmospheric model).

1. Introduction

Dispersion models are used to calculate pollutants ground level concentrations based on the information and data about the emission source characteristics, the pollutants nature, structure of the surrounding environment and meteorological conditions. Dispersion models are widely used to simulate different pollution scenarios, in a current moment, in the past and future. Besides the application for scientific and research purposes, many dispersion models are commonly used for regulatory requirements, air quality assessments and in order to establish critical pollution scenarios.

Knowing the model's characteristics, algorithms used and the results obtained by applying them is important in terms of determining which algorithms can be modified, or which parts of some model are better than those from other models and may be adapted for use in other models with sufficient accuracy.

In the past ten-fifteen years, a group of scientist from Faculty of Technical Sciences, University St. Climent University in Bitola, Republic of Macedonia, has been work on the development and evaluation of regulatory dispersion model that could be used by the government and other law authorities, as well as scientific and academic organizations in order to use it as tool to estimate current and future pollution scenarios from thermal power plant stacks as one of the biggest air polluters.

As the result of these efforts many scientific papers and pollution assessment have been made, and some of them are point out in this paper.

Also, according to the results of these analyses, scientific group took steps to improve model MADAM performances. Certain steps had been undertaken in aim to adjust some of the procedures used in regulatory dispersion model MADAM. The idea was to show that there are several ways to make models better, and that appropriate combination of these methods and tools can be very beneficial for the overall model performances. Results of these efforts were development of model MADAM new variants. All of them have been put it in the process of evaluation, resulting in model variant 4 as most appropriate to use, producing best results in the model evaluation process and its implementation.

The paper is organized as follows: Section 2 gives overall categorization of dispersion models; Section 3 presents general characteristics of dispersion model MADAM, and cases of its application in evaluating air dispersion pollution from Thermal power plant Bitola, Macedonia; Also, Section 2 presents basic correction made in the model MADAM algorithms, and the comparison of the evaluation results using BOOT procedure for several different models, including all model MADAM variants; Section 4 presents general conclusions made on the basis of the presented analysis and data in the paper.

2. Dispersion Models Categorization

Today, there are number of dispersion models which are developed and used worldwide. They all have certain characteristics such as: the hypothesis on which are based, the minimum amount of data necessary for their application, the coverage degree of atmospheric and dispersion processes, calculation accuracy, the application area, etc.

Knowing the model's characteristics, algorithms used and the results obtained by applying them is important in terms of determining which algorithms can be modified, or which parts of some model are better than those from other models and may be adapted for use in other models with sufficient accuracy.

A number of authors and agencies offer different ways for dispersion models categorization, but due to the wide range of features, every model can simultaneously belong to different groups.

U.S. Environmental Protection Agency categorizes dispersion models on several grounds. They can be divided into four groups: Gaussian, Numerical, Statistical and Physical models. Also, according to USEPA, there are models with special purposes such as models for ozone, carbon monoxide, nitrogen dioxide, particulate matter and others.

Lately, models are more commonly categorized as models from old and new generation (new generation models) [1]. This categorization is made according to the period in which they were formed, but also based on the period when theoretical foundations on which they are based were established.

Dispersion models are used for different purposes, but likely they have major application in regulatory processes. The models for legislation needs are used to achieve two main goals, as tool for predicting air pollution condition and to provide detailed interpolation concentration's maps between the measured data using receptors monitoring stations.

The regulatory models results are used in making decision for allowable emissions levels, in the design phase for new industrial buildings and roads to assess their impact on ambient air quality.

Generally, regulatory models should provide information about the spatial distribution of pollutants concentrations when high episodic concentrations occurred, and data on the expected mean concentrations for a longer time period. Classical and modified Gaussian models are usually used as regulatory dispersion models.

The models of Gaussian type are widely used, easy to apply and all their positive and negative characteristics are well defined. They are based on the assumption that the pollutants dispersion at various distances from the source is based on the Gaussian distribution in horizontal and vertical direction and formulation is derived assuming stationary conditions.

Older generation Gaussian models who have found largest application are R91, ISCST3 and others, while as a modified Gaussian models or new generation models are commonly used ADMS, AERMOD, OML and others. Several Gaussian dispersion models are developed by the individual activities of different research groups, among which are included: HPDM, RTARC, Safe-Air, IFDM, etc.

- Top of Form

Particularly interesting for our analysis, in terms of applying some algorithms from its original source code for present conditions in the Republic of Macedonia, is Danish regulatory model OML.

OML model is a new generation Gaussian dispersion model that can be applied in rural or urban conditions, within the local spatial scale up to 20 km from the emission source. The latest official version of this model was published in 2001 [2], while during 2007 revised research version was issued [2], which is still subject to analysis and is not proposed for official use.

The new generation models, as OML, continuously descript atmosphere stability using quantities such as heat flux sensitive H_{SF}, Monin-Obukhov length L, the mixing layer height h_m, and in a quite complex and detailed way calculate dispersion coefficients σ_y and σ_z. Also these models are using contemporary features such as plume partial penetration.

3. Regulatory Dispersion Model MADAM

Model MADAM (MAcedonian Dispersion Atmospheric Model) belongs to Gaussian models, and is developed to be adopted as a regulatory model in the Republic of Macedonia [3-5].

It is widely used in determining the existing level of air pollution, in the case of emission from thermal power plants and other industrial sources in our country. Also, this model is used for simulation of various air pollution scenarios, in normal and accident operating conditions and various external influences (meteorological, terrain configuration, etc.).

We can see in Figs. 1-4 examples of calculated ground level concentrations in the case of emission from Thermal power plant Bitola, which satisfies over 70% of the Macedonia electricity needs.

Figs. 1 and 2 show SO_2 and PM10 highest short-term (one hour) concentrations during normal power plant operation.

Figs. 3 and 4 simulate scenario of possible contamination with particular matters in accident conditions. Fig. 3 shows PM10 concentrations when ES filter of plant units Bitola 1 and 2 works with 50% of its capacity, while Fig. 4 shows PM10 concentrations when ES filter of plant units Bitola 1 and 2 does not work at all.

In recent years, MADAM was subject to a numerous analysis and corrections in its algorithms, in order to achieve better performance under the specific conditions of its application in Macedonia.

Thus, the following corrections in its algorithms were made:

- The model MADAM algorithm is adopted to handle cases when wind speed is lower than 1 [m/s], unlike other Gaussian models who cannot give a realistic picture of pollution in low wind speeds conditions;
- Atmosphere conditions and classification from the model OML is applied, which removes shortcomings from in-continuous description using stability classes [5];
- Unlike the previous calculating method of the dispersion coefficients σ_y and σ_z, based on the Pasquill-Gifford equations, the new MADAM variant solutions are using expressions from the model OML [5];
- The algorithm for plume partial penetration from model OML is applied in model MADAM variant solution v.3 [5].

Inverse calculations methods are applied in several variant solutions of regulatory model MADAM. Determining new values of certain influential parameters in variant solutions v.1 and v.3 of model MADAM was analyzed. Researches were conducted using experimental databases from MVKit (model validation kit) [6, 9-11]. The latest available model MADAM version v.4 was developed as a result of new defined values of some specific analyzed parameters.

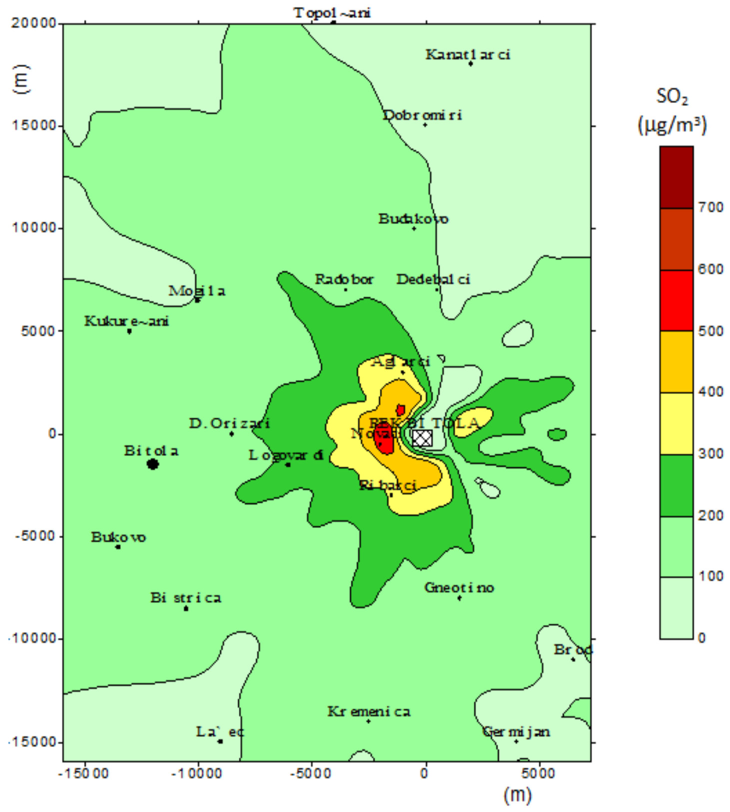

Fig. 1 First highest short-term (1 hour) SO_2 [μg/m^3] ground level concentrations.

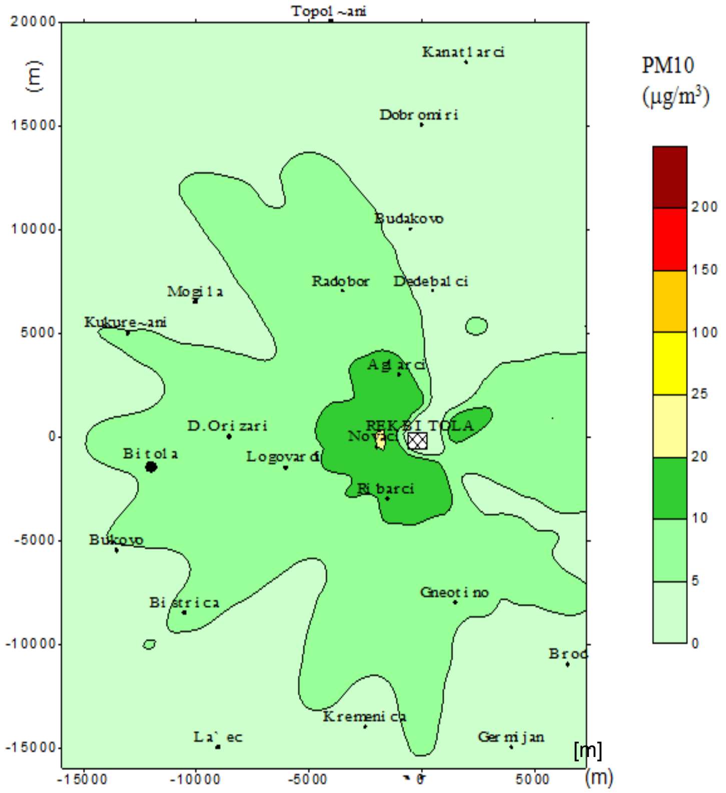

Fig. 2 First highest short-term (1 hour) PM10 [μg/m^3] ground level concentrations.

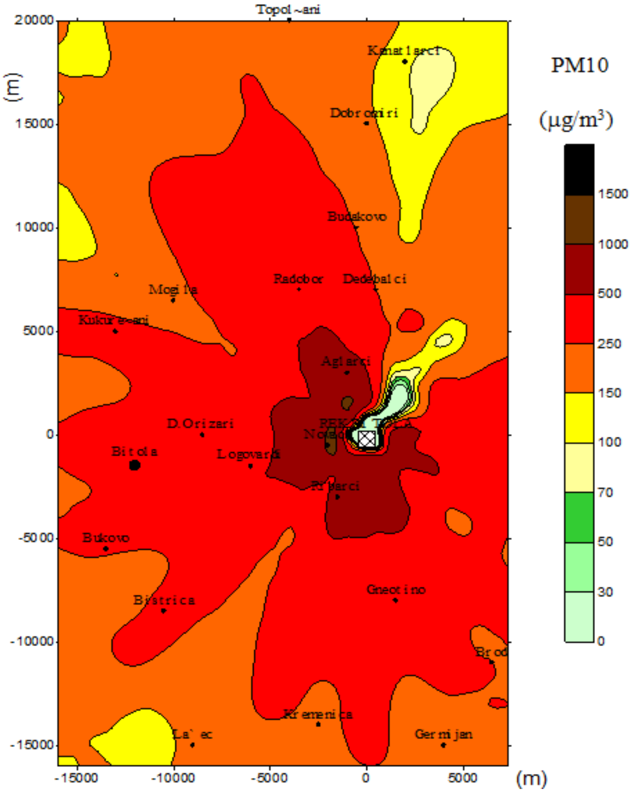

Fig. 3 Highest short-term (1 hour) particular matter PM10 [µg/m^3] ground level concentrations when ES filter of units Bitola 1 and 2 works with 50% of its capacity.

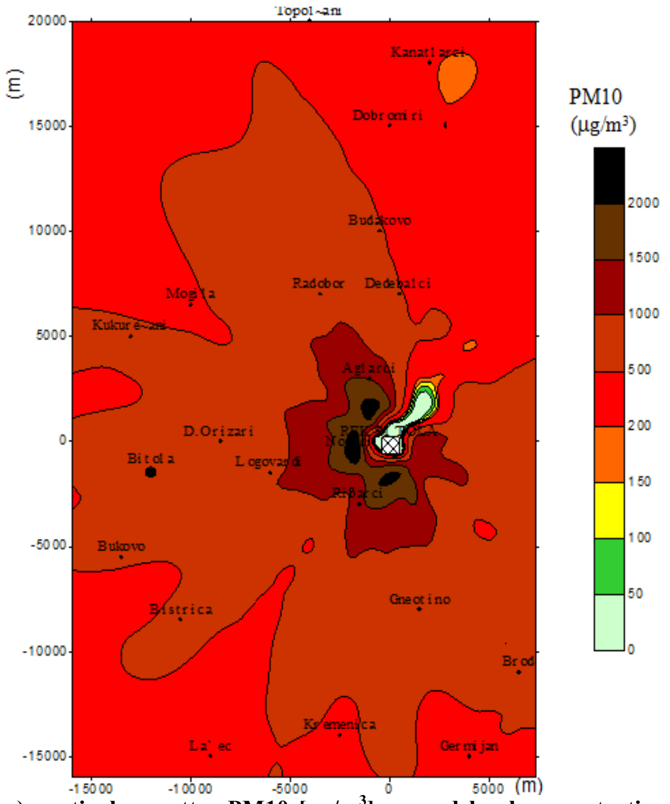

Fig. 4 Highest short-term (1 hour) particular matter PM10 [µg/m^3] ground level concentrations when ES filter of units Bitola 1 and 2 does not work at all.

Table 1 Model evaluation results using BOOT procedure—database Kincaid SF_6, Q3.

	Mean	Sigma	Bias	NMSE	R	FAC2	FB
Measurment	54.34	40.25	0.00	0.00	1.00	1.00	0.00
MADAM v.1	35	45.15	19.54	1.42	0.374	0.476	0.438
MADAM v.3	48	49.00	6.13	1.12	0.283	0.515	0.120
MADAM v.3.1	55	54.52	-0.76	1.02	0.347	0.550	-0.014
MADAM v.4	44	47.54	9.92	0.94	0.444	0.536	0.201
HPDM	44.84	38.55	9.50	0.75	0.44	0.57	0.19
OML	47.45	45.48	6.89	1.24	0.15	0.55	0.14
AERPOL	42.05	31.90	11.64	1.09	0.13	0.57	0.24
Safe-Air	34.89	31.50	19.45	1.52	0.04	0.39	0.44
ISCST3	30.00	60.00	24.30	2.80	0.26	0.28	0.58
AERMOD	21.80	21.80	32.60	2.10	0.40	0.29	0.86
ADMS4	48.50	31.50	5.90	0.60	0.45	0.68	0.11

The indicators derived on the basis of the implemented evaluation procedures (BOOT procedure [7], of the characteristics of the original model variant v.1, intermediate versions v.3 and v.3.1., and the final version v.4, together with data from comparison of these results with the evaluations results of some world-known and widely used models, are given in Table 1.

These data provide a realistic basis to determine that due to the innovation of the model algorithms, by introducing new solutions and implementing the results of applied inverse procedures, we have made progress in the model MADAM performances, so it can be included among the group of models with solid performance according the criteria defined by Ref. [8].

Namely, from these verifications data can be seen that the model reaches values for the data fraction within a factor of two compared to the measured concentrations greater than 50%, FAC2 > 0.5, and fractional deviation $|FB| < 0.3$, while random, stochastic data scatter represented by the value of the normalized intermediate-square error NMSE is less than 1.5 [8].

4. Conclusions

Development, evaluation and improvement of dispersion models performances are goals that inspire all scientific and research groups in this area.

Generally, experiences regarding the introduction of new algorithms and methods for the calculation of certain influential factors and the inverse procedure application in dispersion models are positive.

Namely, the results from the application of these modifications in the regulatory model MADAM showed that it is possible to use them as an option for improving the model performances. This statement is evident from the results of the evaluation procedure, but level of success depends on more subjective and objective circumstances.

References

[1] K.B. Schnelle, P.R. Dey, Atmospheric Dispersion Modeling Compliance Guide, McGraw-Hill, New York, 1999.

[2] H.R. Olesen, R. Berkowicz, P. Løfstrøm, OML: Review of Model Formulation, NERI Technical Report 609, National Environmental Research Institute, University of Aarhus, 2007, p. 130.

[3] I. Andreevski, G. Kanevce, L. Kanevce, A. Markoski, S. Stavreva, Pollutants dipersion modeling using classical and modified Gaussian models, in: 15th Symposium on Termal Science and Engineering of Serbia, Sokobanja, Serbia, Oct.18-21, 2011.

[4] G.H. Kanevce, L.P. Kanevce, Dispersion modeling for regulatory applications, Thermal Science 10 (2) (2006) 141-154.

[5] I. Andreevski, Inverse concept application in dispersion models development and verification, Ph.D. Thesis,

Faculty of Technical Sciences-Bitola, Bitola, Macedonia, Jul. 2008.

[6] Model Validation Kit, HARMO, MVKit, http://www.harmo.de/kit (accessed Oct. 6, 2009).

[7] J.C. Chang, S.R. Hanna, Technical Descriptions and User's Guide for the BOOT Statistical Model Evaluation Software Package, Version 2.0, Jul. 10, 2005.

[8] J.C. Chang, S.R. Hanna, Air quality model performance evaluation, Meteorol. and Atmos. Phys. 87 (2004) 167-196.

[9] I. Andreevski, G. Kanevce, A. Markoski, Dispersion models result's improvements using inverse approach, in: Proceeding of the 13th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purpose in Paris, France, Jun. 1-4, 2010, pp. 977-981.

[10] I. Andreevski, G. Kanevce, L. Kanevce, Mathematical dispersion models—Possibilities and conditions for inverse estimations application, in: The 9th International Symposium: Power and Process Plants, Dubrovnik, Croatia, Sept. 29-Oct. 1, 2010.

[11] I. Andreevski, G. Kanevce, L. Kanevce, Inverse estimations—Application in air pollution modelling, in: Faculty of Technical Sciences Annual Proceedings 2011, Faculty of Technical Sciences-Bitola, University St Clement Ohridski-Bitola, Macedonia, Oct. 2011.

International Journal of
Mechanical Engineering and Automation
Volume 2, Number 1, January 2015

Ethan Publishing Company
1902 Merced Ave South El Monte, CA 91733
IJMEA@ethanpublishing.com

9 772333 917157 01