Journal of the University of Chemical Technology and Metallurgy, 44, 1, 2009, 39-43

MATHEMATICAL MODELLING OF THE DISTRIBUTION OF PERSISTENT ORGANIC POLLUTANTS EMITTED FROM TPP "BRIKEL" EAD, TPP "MARITSA EAST 2" EAD AND TPP "ENEL – MARITSA EAST 3" AD

V. Kyoseva, Ev. Sokolovski

University of Chemical Technology and Metallurgy
8 Kl. Ohridski, 1756 Sofia, Bulgaria
E-mail: vania225@abv.bg; sokolovski@abv.bg

Received 15 November 2008
Accepted 02 February 2009

ABSTRACT

The thermal power plants "Maritsa East 2" EAD, TPP "Enel-Maritsa East 3" AD and TPP "Brikel" EAD are among the emitters of persistent organic pollutants (POPs) - polychlorinated dibenzo-para-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs), in Bulgaria. Mathematical modelling and computer simulation of their distribution in the ground layer of the atmosphere using the computer package PLUME was made.

Keywords: mathematical modelling, computer simulation, persistent organic pollutants, thermal power plants (TPP), ground-layer concentration.

INTRODUCTION

The Stockholm Convention on Persistent Organic Pollutants (POPs) adopts the "precautionary approach", so that where there are treats of serious or irreversible damage, the lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation [1-3].

The thermal power plants (TPP) with capacity of 300 MW, 50-300 MW and below 50 MW, are among the biggest sources generating and emitting POPs into the environment according to the EP - CORINAIR-94, SNAP-94 Methodology. Three TPP from the Maritsa East complex (one of the most important electricity suppliers in Bulgaria): TPP "Maritsa East 2" EAD, TPP "Enel – Maritsa East 3" AD and "Brikel" EAD are the biggest source of PCBs and PCDD/Fs in the country [4, 5].

The aim of the present modelling is to visualize the POPs emissions distribution for 2004 through showing pollutants concentrations in the most probable direction of distribution according to the wind rose for the region, as well as to assess the ground layer atmospheric air pollution in the region of the examined sources.

METHODOLOGY

The mathematical modelling and computer simulation of PCB, and PCDD/Fs distribution in the atmospheric air was accomplished with simulation computer package PLUME [6]. This package deals with three basic problems, and the one applied for the purpose of the present study is calculation of the PCB and PCDD/Fs concentration in the ground layer of the atmosphere when the parameters of the source, the emission and the meteorological conditions are known.

The simulation computer package is based on the Gaussian plume model theory, which makes the assumption for normal distribution of the pollutants concentration along the two perpendiculars to the wind direction. The latter is at the ground of the methodology for calculation the distribution of pollutants emitted from immobile sources in Republic of Bulgaria, confirmed in the country.

The modelling of the distribution of the pollutants emitted by the three TPPs is done for two of the classes of atmospheric stability – class A and class B. For the types of the atmospheric stability the classification of Pasquill-Gifford is used. For atmospheric stability – class A, the emitted pollutants are deposited on an area near the sources, and the concentrations are the highest. The area of simulation has a length 3 000 m and width 3 000 m.

For atmospheric stability – class B, the emitted pollutants are deposited considerably far away from the source. This is the reason why the area of simulation is much bigger - length 15 000 m and width 15 000 m.

The north-east direction was chosen taking into account the wind rose typical for the region.

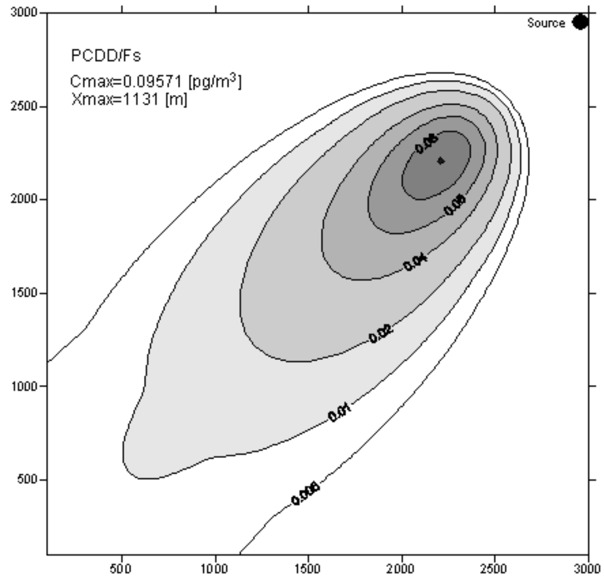

Fig. 1. Isolines of the ground layer concentration of PCDD/Fs, emitted from TPP “Brikel” EAD, in case of class A of the atmospheric sustainability and north-east wind direction.

RESULTS AND DISCUSSION

Data in Table 1 show the results from the mathematical modelling of PCBs and PCDD/Fs distribution emitted from TPP “Brikel” EAD. Some of the results are illustrated on Figs. 1 and 2.

Fig. 1 shows the isolines of the ground layer concentrations of PCDD/Fs emitted from TPP “Brikel” for class A of atmospheric stability. The maximum is 0.09571 pg m^{-3} and it is observed at distance 1131 m from the last source. For class B of atmospheric stability the maximum PCDD/Fs concentration 0.03492 pg m^{-3} was observed at 3818 m away from the source.

Fig. 2 shows the isolines of the ground layer concentrations of PCBs emitted from the same source for class B of atmospheric stability. In this case the maximum PCBs concentration is 0.01326 ng m^{-3}, registered at 3818 m away from the source. For class A of atmospheric stability, the maximum concentration of PCBs is 0.03941 ng m^{-3}, registered at 1131 m away from the source. In the region of Galabovo the concentrations vary between 0.0045-0.00015 ng m^{-3}.

The results obtained from the mathematical modelling of the distribution of PCBs and PCDD/Fs emit-

Table 1. Results from the mathematical modelling of the distribution of PCBs and PCDD/Fs emitted from TPP “Brikel” EAD.

Parameters	Area of simulation	
	3000 x 3000 m	15000 x 15000 m
PCBs		
Maximum concentration, C_{max}, ng m^{-3}	0.03941	0.01326
Maximum distance, X_{max}, m	1131	3818
PCDD/Fs		
Maximum concentration, C_{max}, pg m^{-3}	0.09571	0.03492
Maximum distance, X_{max}, m	1131	3818

Table 2. Results from the mathematical modelling of the distribution of PCBs and PCDD/Fs emitted from TPP “Maritsa East 2” EAD.

Parameters	Area of simulation	
	3000 x 3000 m	15000 x 15000 m
PCBs		
Maximum concentration, C_{max}, ng m^{-3}	0.1443	0.02253
Maximum distance, X_{max}, m	1345	6011
PCDD/Fs		
Maximum concentration, C_{max}, pg m^{-3}	0.26192	0.08985
Maximum distance, X_{max}, m	1555	6011

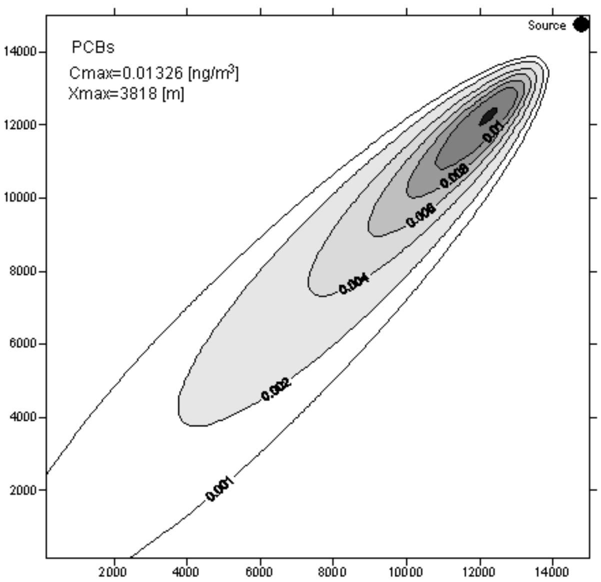

Fig. 2. Isolines of the ground layer concentration of PCBs, emitted from TPP “Brikel” EAD, in case of class B of the atmospheric sustainability and north-east wind direction and speed of 3.2 m s^{-1}.

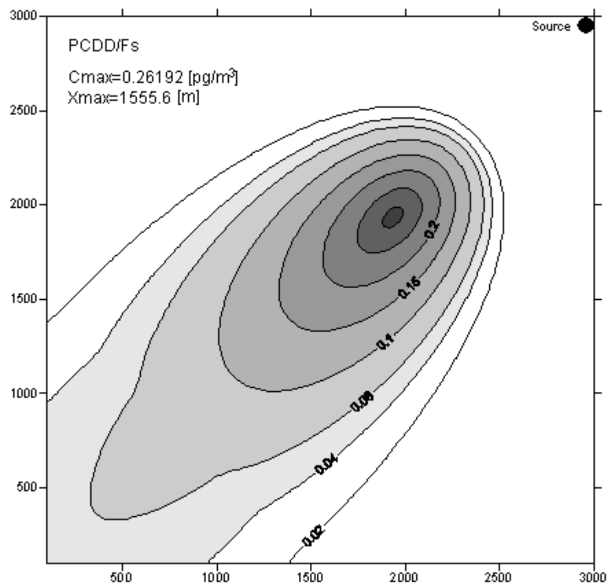

Fig. 3. Isolines of the ground layer concentration of PCDD/Fs, emitted from TPP “Maritsa East 2” EAD, in case of class A of the atmospheric sustainability and north-east wind direction.

ted from TPP “Maritsa East 2” EAD are presented in Table 2.

Fig. 3 shows the isolines of the ground layer concentration of PCDD/Fs, emitted from TPP “Maritsa East 2” EAD in the case of class A of atmospheric stability and north-east wind direction – the maximum observed concentration is 0.26192 pg m^{-3}, at distance of 1555 m from the last source. For class B of atmospheric stability the maximum PCDD/Fs concentration is 0.08985 pg m^{-3}, observed at 6011 m away from the source.

In the case of class A of atmospheric stability the maximum concentration of PCBs was registered at 1 345 m away from the source (0.1443 ng m^{-3}). Fig. 4 shows the isolines of the ground layer concentration of PCBs, emitted from TPP “Maritsa East 2” EAD in case of class B of atmospheric stability and north-east wind direction with speed 3.2 m s^{-1}. The maximum concentration observed was 0.02253 ng m^{-3} at 7848 m.

The results from the mathematical modelling of the distribution of PCBs and PCDD/Fs emitted from

Table 3. Results from the mathematical modeling of the distribution of PCBs and PCDD/Fs emitted from TPP "Enel – Maritsa East 3" AD.

Parameters	Area of simulation	
	3000 x 3000 m	15000 x 15000 m
PCBs		
Maximum concentration, C_{max}, ng m^{-3}	0.06794	0.0164
Maximum distance, X_{max}, m	1414	6576
PCDD/Fs		
Maximum concentration, C_{max}, pg m^{-3}	0.1694	0.03982
Maximum distance, X_{max}, m	1414	6576

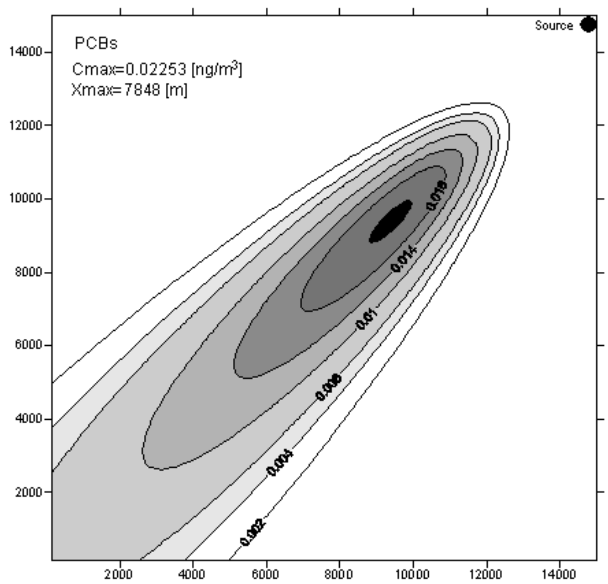

Fig. 4. Isolines of the ground layer concentration of PCBs, emitted from TPP "Maritsa East 2" EAD, in case of class B of the atmospheric sustainability, north-east wind direction and speed of 3.2 m s^{-1}.

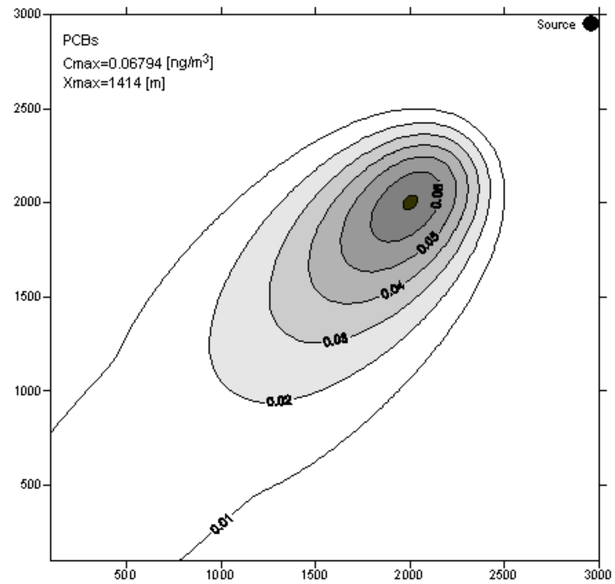

Fig. 5. Isolines of the ground layer concentration of PCBs, emitted from TPP "Enel – Maritsa East 3" AD, in case of class A of the atmospheric sustainability and north-east wind direction.

TPP "Enel – Maritsa East 3" EAD are summarized in Table 3.

Fig. 5 shows the isolines of the ground layer concentration of PCBs, emitted from TPP "Enel – Maritsa East 3" AD in the case of class A of atmospheric stability and north-east wind direction. In this case the maximum concentration of PCBs is 0.06794 ng m^{-3} at 1 414 m away from the source. In the case of class B of atmospheric stability, the maximum PCB's concentration was 0.0164 ng m^{-3}, observed at distance 6576 m from the source.

The data obtained for PCDD/Fs emitted from TPP "Maritsa East 3" are as follows: 0.1694 pg m^{-3} at 1 414 m and 0.0398 pg m^{-3} at distance of 6576 m, accordingly for classes A and B of an atmospheric stability. The case for class B of an atmospheric stability and north-east wind direction with speed 3.2 m s^{-1} is shown on Fig. 6.

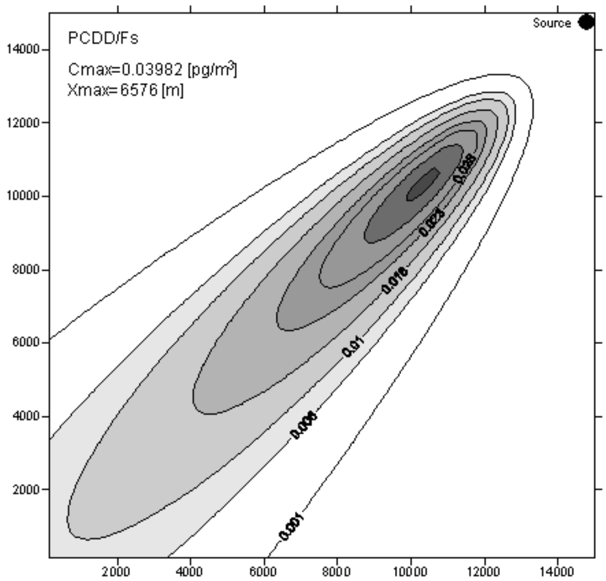

Fig. 6. Isolines of the ground layer concentration of PCDD/Fs, emitted from TPP "Enel – Maritsa East 3" AD, in case of class B of the atmospheric sustainability and north-east wind direction and speed of 3.2 m s^{-1}.

CONCLUSIONS

Based on the mathematical modelling and computer simulation of the PCBs, PCDDs and PCDFs distribution, the following conclusions can be made:

For the two classes of atmospheric stability (A and B) the maximum concentrations of PCBs emitted reach the level of 0.03693 ng m^{-3}. For PCDDs and PCDFs the maximum concentrations are smaller than the maximum allowed concentration for these pollutants - 0.1 ng m^{-3}.

Nevertheless the registered concentrations for the three TPPs were below the requirements, the cumulative effect from the impact of these pollutants should be bear in mind, because of their extremely dangerous and toxic impact on the humans' health and the components of the environment, even in very low concentrations.

REFERENCES

1. SSC (no date): Secretariat of the Stockholm Convention www.pops.int.
2. http://www.chem.unep.ch/pops/.
3. E. Mehmetli, B. Koumanova (eds.), The Fate of the Persistent Organic Pollutants in the Environment, ISBN 978-1-4020-6641-2 (PB), Springer, 2008.
4. Y. Pelovsky, N. Kozarev, Iv. Dombalov, Transboundary Air Pollution Maritza-East Thermal Power Station, Proc. of the 4th International Conference of the Balkan Environmental Association BENA, Journal of Environmental Protection and Ecology, **3**, 3, 2003, 649 – 655.
5. V. Kyoseva, E. Sokolovski, Assessment of the emissions of polychlorinated biphenyls in Republic of Bulgaria, J. Univ. Chem.Technol. Met. (Sofia), **44**, 1, 2009.
6. Methodology for calculation of the height of the emission sources, the distribution and the expected concentrations of pollutants in the ground layer of the atmosphere, Ministry of Environment and Waters, 2003, (in Bulgarian).