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ASPECTS REGARDING THE IMPACT OF ENERGY RECOVERY FROM DOMESTIC WASTE ON ATMOSPHERE

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ABSTRACT

The issue of domestic waste neutralization appeared with human civilization but got new dimensions in the context of the present consumer society. The diversity and increasing quantity of domestic waste imposed finding new methods for its neutralization, grouped into two categories, namely recycling and recovery. In the category of domestic waste recovery methods, incineration is mentioned among others. The main drawback of the incineration process is air pollution, which is present when the implementation of gaseous pollutant retention solutions at the source generation is avoided. In order to identify the areas that are potential sources of pollution, the present paper focuses on the dispersion modelling of gaseous pollutants from domestic waste incineration.

KEYWORDS: domestic waste, incineration, modelling, atmosphere

1. Introduction

The amount and complexity of waste make them a genuine challenge for any modern society concerning the identification of neutralizing solutions according to environmental protection standards.

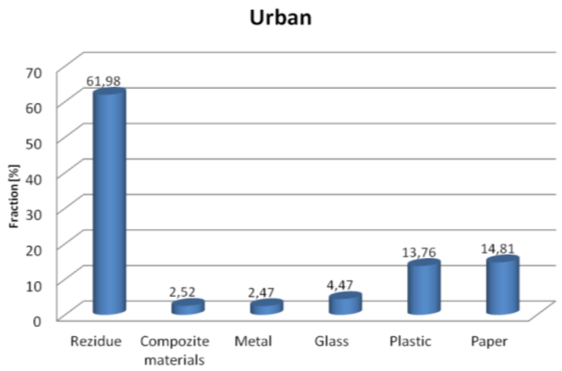
The amount of waste worldwide generated is increasing due to the population growth of 7.3 billion in 2015 compared to 2 billion in 1927, but also due to policies encouraging excessive consumption [1]. Although some sociologists affirm that a high consumption level ensures larger production and thus increases the number of employees, this trend contradicts the primary resource conservation principle. Beyond this controversy on the population's moderate or excessive consumption, the problem of consumption waste neutralization remains topical.

The waste complexity derives from the plurality of substances and materials discovered in scientific research activity in various fields. For instance, according to ChemID*plus* database, in chemical industry alone about 408,898 compounds are known. This requires from the scientific community to identify some waste treatment and neutralization solutions (in particular, for industrial ones) specific to their composition.

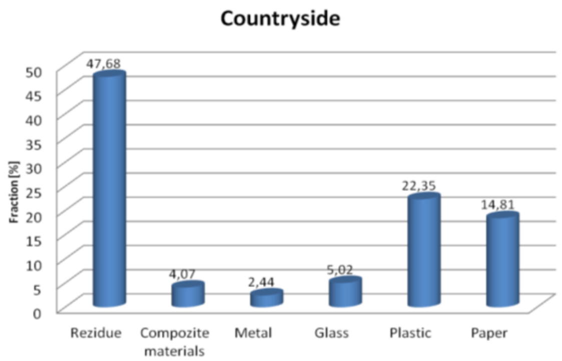
Normally, when domestic waste removal is done selectively, the waste should have a low toxicity effect on the environment. In Romania, environmental education being still in an early stage, the infrastructure design for waste recycling is not 100% operational and the domestic waste contains toxic or potentially recyclable elements. Thus, in domestic waste composition one can find recyclable waste such as plastic materials, glass, paper and cardboard, aluminum and steel cans, etc. The dangerous waste includes batteries, residues of chemical substances used in households (nail polish, paint, diluents), spray tubes, etc.

The Eco-Rom Packaging firm, specialized in waste recycling in Romania, carried out a one year experimental study in order to establish precisely the waste composition in urban and rural areas Fig. 1 [3]. Figure 1 shows the important recycling potential of domestic waste: 52.32% in rural areas and 38.02% in urban areas. According to the Sustainable Development concept, the recovery of recyclable components from urban waste is an obligation for the current generation in order to avoid prejudicing the future generations.

In Romania, the main way of urban waste elimination is storage. Although this method is less expensive than others it also has some disadvantages such as occupying land that could be extended to other activities, the generation of greenhouse gaseous emissions, low density waste spreading to adjacent areas due to airflows, etc.



a. in urban areas



b. in the countryside

Fig. 1. *Waste composition*

A reduction of municipal waste deposited in landfills consists of the recovery of recyclable components, but a removal of 80-85% is achieved only by thermal treatment.

2. Public waste incineration

The thermal treatment of public waste can be achieved by several methods among which we recall: plasma pyrolysis (PGM - Plasma Gasification Melting), incineration and co-incineration [4]. In Romania, the thermal treatment of domestic waste is achieved by co-incineration in cement factories in the clinker production process.

In 2013 in the urban area, each Romanian citizen produced an average amount of 346 kg of domestic waste with a 38.02% recyclable rate; the countryside population produced only 95 kg of domestic waste of which 52.32% is recyclable. Considering that Romania would fulfill its environmental obligations and recycle 50% of the recyclable domestic waste up to 2020, the waste amount that needs to be discharged is a real challenge for the authorities.

Waste incineration is a viable solution for unrecyclable domestic waste removal provided that the best available techniques are implemented (the BATNEEC principle - Best Available Techniques Not Entailing Excessive Costs) for retaining pollutants at source. Placing an incinerator designed for medical waste treatment is a very important issue because its potential abnormal operation and especially in case of damage the equipment should not affect neighboring areas.

3. Evaluation of gaseous pollutant dispersion discharged through the chimney of municipal waste incineration plant

3.1. The INCREST incinerator

As follows from the above, based on the Gaussian model for a continuous source, this study evaluates the atmospheric dispersion of particulate matter generated by an INCREST incinerator designed for the thermal treatment of municipal waste in Braila municipality, Romania.

The thermic balance calculus of the INCREST type incinerator (Fig. 2) [6] was accomplished after the following assumptions:

- the incinerator's location was considered on the old plant platform Celhart Donaris located at 10 km from Braila city;

- the equipment services Braila county population. According to the latest census in 2011, the county population is 304,900 citizens and the municipality 168,300 citizens. Thus, the domestic waste volume generated within the county in one year is 71,208 tons of which 35,604 tons would remain to eliminate if 50% of them would be recycled;

- the incinerator capacity is 34,200 tons/year and the flow is variable depending on the season, in the range of 4-5 tons/hour;

Based on the calculus model of thermic balance presented in [6], the following parameters were found:

- the ash emission rate is Q = 0.44 g/s;

- the air flow evacuated on chimney is V = 2 m^3/s;

- the evacuated gas temperature is 135 ^oC.

3.2. Gaussian model for continuous sources

As in [7, 9], the most general mathematical expression of Gaussian dispersion equation for a continuous emission source is:

$$X(x,y,z,H)=\frac{Q}{2\pi u\sigma_y\sigma_z}\exp\left[-\frac{y^2}{2\sigma_y^{\ 2}}\right]\cdot \cdot\left\{\exp\left[-\frac{(z-H)^2}{2\sigma_z^{\ 2}}\right]+\exp\left[-\frac{(z+H)^2}{2\sigma_z^{\ 2}}\right]\right\} \tag{1}$$

As the interest lies on the degree of pollution on people, we considered the height z = 0 (ground level) that leads to a simplified equation as follows:

$$X(x,y,0,H)=\frac{Q}{2\pi u\sigma_y\sigma_z}\cdot \cdot\exp\left[-\frac{y^2}{2\sigma_y^{\ 2}}\right]\exp\left[-\frac{H^2}{2\sigma_z^{\ 2}}\right] \tag{2}$$

where: X (x, y, z, H) – is the concentration of the pollutant in the atmosphere, g/m^3; u – wind speed, u = 4-6 m/s, as in Fig. 2; σ_y, σ_z - the parameters of the dispersion or standard deviation; x - distance downwind to chimney, x = 2000 m; y - wind direction transverse distance from the center line of the pollutant plume, m; z - the height in the vertical direction from the ground, m; H - effective height of the pollutant plume, m.

$$H = h + \Delta h \tag{3}$$

h – gas exhaust chimney height, h = 50 m; Δh - pollutant plume ascension.

Determining the thickness of the pollutant plume Δh using the mathematical relation:

$$\Delta h=\frac{1.6F^{1/3}x^{2/3}}{u} \tag{4}$$

where: F - Buoyancy flow.

The Buoyancy flow is calculated with:

$$F=\frac{g}{\pi}V\left(\frac{T_s-T_a}{T_s}\right) \tag{5}$$

where: g – acceleration of gravity; V – gas volume to chimney, V = 2 Nm^3/s; T_s – exhaust gas temperature to chimney; T_s = 135 °C; T_a – ambient temperature, T_a = 25 °C.

In order to determine the dispersion parameters (Briggs model), the relations developed by Caraway [9] were used:

$$\sigma_y = cx^d \tag{6}$$

where: c, d - are coefficients that depend on atmospheric stability and distance of the valuation (chosen tabular [9]); x - distance for which the valuation is made, x = 2000 m.

$$\sigma_z = ax^b \tag{7}$$

where: a, b - are coefficients that depend on atmospheric stability and distance of the valuation (chosen tabular [9]); x - distance for which the valuation is made.

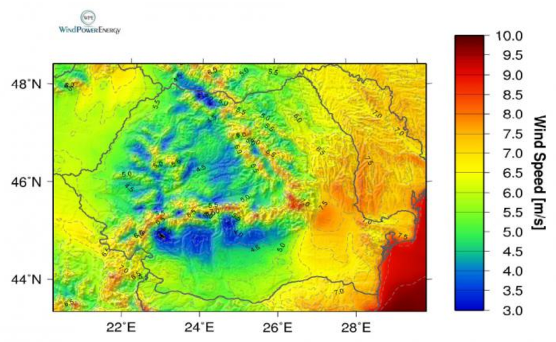


***Fig. 2.** Wind map of Romania* [8]

The pollutant dispersion charts resulting from domestic waste incineration (in our case the pollutant being ash) were drawn up for different atmospheric conditions in order to identify the areas affected by pollution. Thus several iterations of the Gaussian model were achieved for a continuous source in the following numerical combinations of the atmospheric parameters:

- the wind speed 4 m/s;
- the atmospheric stability class E, nighttime with partly cloudy sky;
- the atmospheric stability class C, daytime with moderate insolation;
- the wind speed 5 m/s,
- the atmospheric stability class D, nighttime with partly cloudy sky;
- the atmospheric stability class C, daytime with moderate insolation;
- the wind speed 6 m/s,
- the atmospheric stability class D, nighttime with partly cloudy sky;
- the atmospheric stability class C, daytime with moderate insolation.

The classification of atmospheric stability is given in Table 1 [9].

The diffusion parameters evaluated using the calculation formulas presented in the paper [9] were integrated in the code source intended to solve the Gaussian equation for a continuous pollution source that was developed in the programming field Matlab by Holzbecher E. in the paper [10].

Table 1. *The stability classification* [9]

The wind speed on surface (m/s)	Daytime			Nighttime	
	Strong	Mild	Light	Thin covered in clouds or > 4/8 Low nebulosity	< 3/8 nebulosity
< 2	A	A- B	B	-	-
2- 3	A- B	B	C	E	F
3- 5	B	B- C	C	D	E
5- 6	C	C- D	D	D	D
> 6	C	D	D	D	D

a. The ash concentration distribution for a continuous source with assumption of the following conditions: wind speed, v = 4 m/s; the atmospheric stability class E, nighttime, partly cloudy sky, Fig. 3.

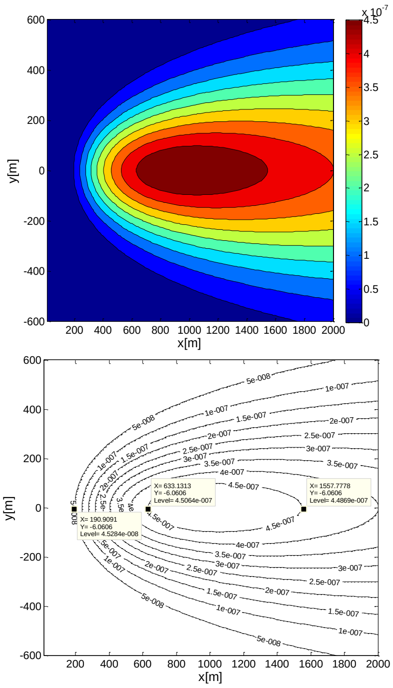


Fig. 3. *Gaussian distribution of pollutant concentration for a continuous source*

b. The ash concentration distribution for a continuous source with assumption of the following conditions: wind speed, v = 4 m/s; the atmospheric stability class C, daytime, moderate insolation, Fig. 4.

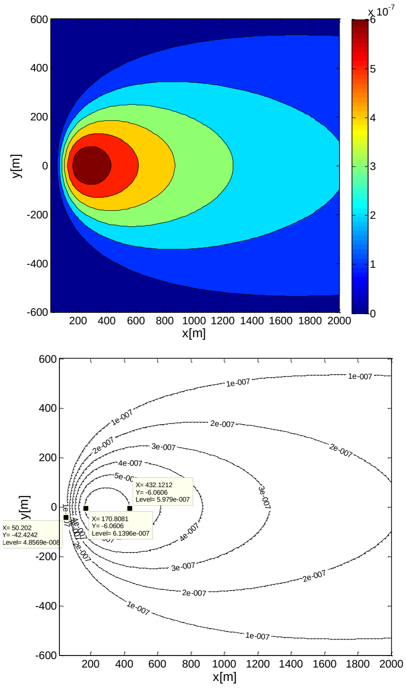


Fig. 4. *Gaussian distribution of pollutant concentration for a continuous source*

c. The ash concentration distribution for a continuous source with assumption of the following conditions: wind speed, v = 5 m/s; the atmospheric stability class C, daytime, moderate insolation.

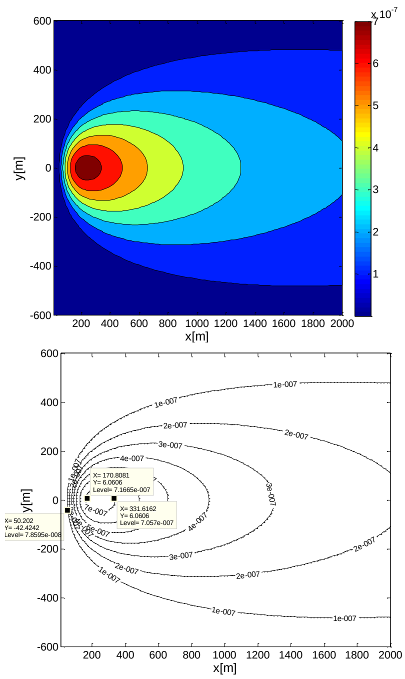


Fig. 5. *Gaussian distribution of pollutant concentration for a continuous source*

d. Pollutant concentration distribution for a continuous source for the next conditions: wind speed, v = 5 m/s; the atmospheric stability class D, nighttime, partly cloudy sky.

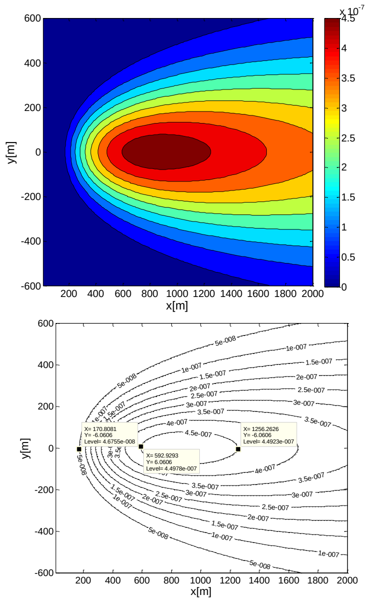


Fig. 6. *Gaussian distribution of pollutant concentration for a continuous source*

e. Pollutant concentration distribution for a continuous source for the next conditions: wind speed, v = 6 m/s; the atmospheric stability class D, nighttime, partly cloudy sky.

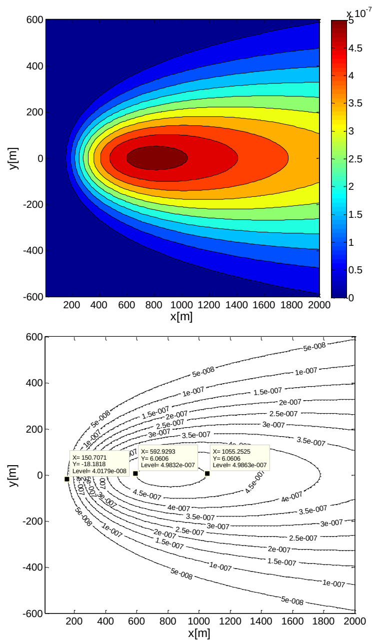


Fig. 7. *Gaussian distribution of pollutant concentration for a continuous source*

f. Pollutant concentration distribution for a continuous source for the next conditions: wind speed, v = 6 m/s; the atmospheric stability class C, daytime, moderate insolation.

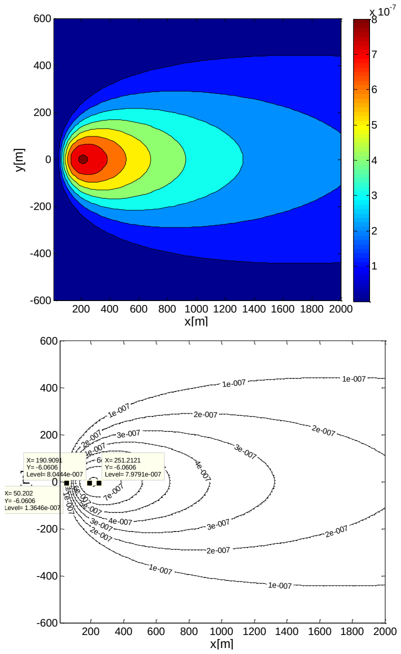


Fig. 8. *Gaussian distribution of pollutant concentration for a continuous source*

Chart analyses defined for the same wind speed and different atmospheric stability class outlined the following issues:

- the ground level pollution appears to the gases discharge point at a minimal distance of 50 m nighttime, respectively of 190 m daytime;

- the pollutant maximum concentration area begins at a distance of 633 m nighttime, respectively of 170 m daytime;

- the differences between the distances provided above for both moments of the day is explained by the different weather conditions. It is noted that during daytime the pollutant tendency is to remain concentrated near the chimney due to insolation.

The maximum concentration of ash released into the atmosphere is of 0.8 μg/m^3. The indicator PM10 (particulate matter with a diameter of up to ten micrometers), according to annex no. 3 of Law no. 104/2011 concerning the ambient air quality, in force since 28 July 2011 (repeals Order MAPM no. 592/2002) has a limit value during the mediation period of 24 hours for human health protection of 50 μg/m^3 (not to be exceeded more than 35 times in a calendar year).

Therefore, there is no exceeding of the limit values imposed by legislation for particulate matter with a diameter of up to ten micrometers.

3. Conclusions

The dispersion analyses of pollutants evacuated from fuel combustion is of great interest for the stage of placing the future industrial facilities because adjacent areas affected by pollution are evaluated for different values of atmospheric parameters. For the industrial units in operation designed for thermal treatment of urban waste, the Gaussian model for pollutant dispersion can also indicate the affected areas in case of incineration system breakdown by identifying the safe location areas of residential neighborhoods.

The study aimed mainly to theoretically evaluate particulate matter dispersion generated by operating a municipal waste incinerator, which can be adapted to dispersion evaluation of other pollutants, such as CO and NO_2.

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