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METHODOLOGY FOR THE HUMAN HEALTH RISK ASSESSMENT FROM THE THERMOELECTRIC PLANTS

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Lucrarea îşi propune să evidenţieze o metodologie de evaluare a riscului asupra sănătăţii populaţiei datorat funcţionării centralelor termoelectrice. Evaluarea ţine seama atât de existenţa macro-poluanţilor (SO_2, NOx, TSP, PM_{10}), cât şi a micro-poluanţilor (organici: PAH cu mar fi B[a]P şi anorganici: metale grele – Ni, Cd ş.a.). Se prezintă deasemenea rezultate care au fost obţinute prin aplicarea unei metode definite de evaluare a riscului cu referire directă la emisiile unei centrale termoelectrice pe cărbune şi efectele pe care acestea le pot avea asupra sănătăţii omului. În conţinutul lucrării sunt evidenţiate şi modalităţile prin care impactul asupra sănătăţii poate fi cuantificabil: în cazul macro-poluanţilor este vorba despre morbiditate sau mortalitate, iar în cazul micro-poluanţilor despre numărul de cazuri de cancer rezultate ca şi o consecinţă a existenţei poluanţilor toxici şi persistenţi.

The paper is presenting an assessment methodology for the human health risk from thermoelectric plants. The proposed health risk assessment is taking into account both macro-pollutants (SO_2, NOx, TSP, PM_{10}) and micro-pollutants (organic: PAH like B[a]P and inorganic: heavy metals – Ni, Cd and others). In addition, some results which can be obtained applying this kind of methodology it was illustrated; it were considered references to the emissions of a thermoelectric plant on coal and the effects on the human health that thermoelectric plant could have. The paper also illustrates the impact quantification possibility in terms of mortality or morbidity for the macro-pollutants and number of additional cancer cases for the micro-pollutants which are toxic and persistent pollutants.

Keywords: thermoelectric plants, emissions, human health risk, pollutants.

1. Introduction

The atmospheric pollution sources can be divided in three major categories: punctual, linear or diffuse air pollution source. The thermoelectric

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plants are punctual sources. The pollutants that generally are taken into account for the impact assessment are the macro-pollutants. From this category of pollutants it is about nitrogen oxides (NOx), sulphur dioxides (SO_2) and total suspended particulate matter (TSP – particles with a diameter higher than 50 μm). In the next part of the paper it will be pointed out which other pollutants emitted by the thermoelectric plants must be analyzed. Furthermore, specific considerations on the health effects of the emitted pollutants from thermoelectric plants in comparison with a waste incineration plant will be made.

2. Thermoelectric plants and air emissions

The thermoelectric plants air emissions in relation to the combustible used are very important aspects. At the European level, the production of the electric energy sector is generally based on new turbo gas combined cycle (TGCC) or on conversion of existing plants to this technology. The TGCC technology has high performance related to the energy production and a low pollution level. It is not the same for coal and combustible oil thermoelectric plants. Considering the fact that in Romania the major part of the thermoelectric plants are on combustible oil or coal the thermoelectric plants on coal will be considered. It was considered this kind of plant in order to make some specific suggestions on a human health impact from thermoelectric plants together with an assessment methodology. The preoccupation for the population health effects from thermoelectric plants resulted from the dedicated studies which evidenced real correlation between the existence of this kind of plants and specific illnesses (for instance bronco pulmonary pathologies both acute and chronic) [1].

Related to thermoelectric plants and pollution, the macro pollutants are representing the first preoccupation. We wanted to underline that for the thermoelectric plants also the micro-pollutants emissions must be quantified and analyzed. The existence of the micro pollutants in the atmospheric emissions can be both organic (for instance, polycyclic aromatic hydrocarbons) and inorganic (heavy metals).

3. Pollutants emissions and health effects

For micro and macro-pollutants emissions separately assessments on human health impact must be done; this is necessary in order to have a realistic and complete risk assessment. If the thermoelectric plant is on combustible oil the possibility of the emission of Polycyclic Aromatic Hydrocarbons (PAH) is very high; between all PAH emitted Benzo[a]Pyren (BaP) is a carcinogenic pollutant which deserves a particular attention. Such a pollutant will be soon considered a tracer of the presence of other carcinogenic PAH. In fact according to a recent Directive (2004/107/CE) [2] an ambient air value of 1 ng/Nm^3 was fixed.

Together with the organic pollutants also the inorganic must be considered. It is about heavy metals as Cadmium, Nickel and Vanadium; these also could induce cancer. Consequently, for the thermoelectric plants an evaluation and also quantifications for the micro-pollutants are necessary to be made.

Related to particulate matter, the legislation air limit concentration for the PM_{10} is asking, while $PM_{2.5}$ or $PM_{0.1}$ are not taking into account. Because the fine or ultra fine particles ($PM_{2.5}$ or $PM_{0.1}$ respectively) are harmful for the human health (more fine the particles are, more dangerous are for the inhalation pathways and as a result pulmonary diseases are inducing) it is resulting that the present legislation it is not complete.

4. Micro-pollutants human health risk assessment methodology

The micro pollutants emitted into the atmosphere have the property to be toxic and persistent. It is known that some of these kinds of pollutants have the property to produce cancer. The proposed methodology for the health risk assessment is identifying the additional number of cancer cases given by a specific pollutant concentration from an identified plant. It is the methodology proposed by United States Environmental Protection Agency (US EPA) in 1998 [3] and updated in 2003 by OEHHA [4] (Fig. 1).

The acceptable risk is 10^{-6}. Once identified the pollutants that are characterizing the emissions of the considered source (thermoelectric plant in our case) the resulted risk is assessed; this must be lower that the acceptable one.

The pathways for which the exposure is calculated are soil ingestion, dermal contact and inhalation. A very important and original aspect respect to the methodology applied until now (for instance in Italy – DICA 2003 [5]) is the diet; for the toxic and persistent pollutants diet is the major route for the human exposure.

Additionally, for the assessed impact a monetary quantification is possible to be done. Because in Romania today micro-pollutants emission concentrations are very difficult to be quantified, we are proposing to realize this kind of evaluation in the next future.

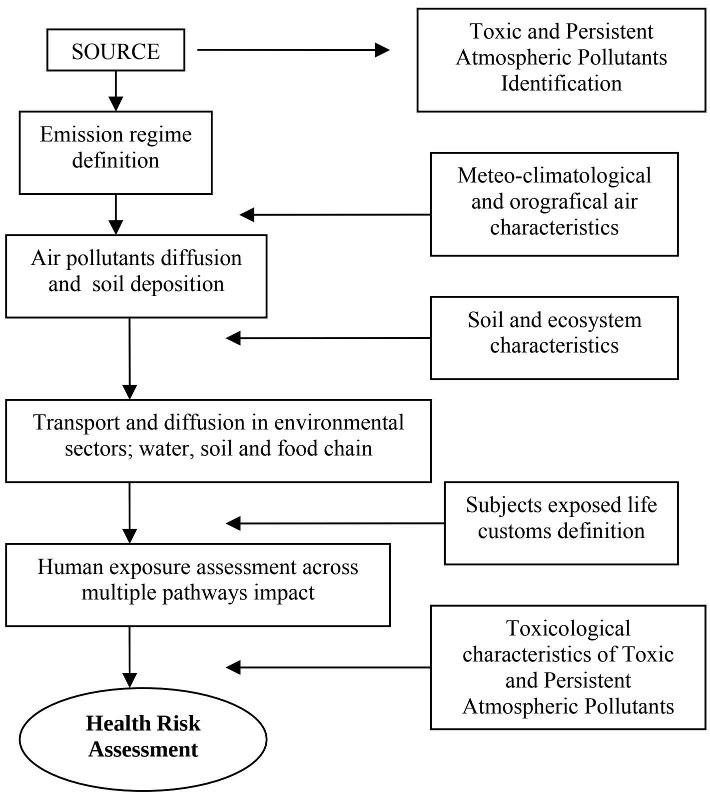

Fig. 1 General diagram of risk assessment methodology (US EPA 1998)

5. Macro-pollutants human health risk assessment methodology

If we want to evaluate the impact on human health from macro pollutants emissions, the population distribution in the impact area plays an important role. Using different GIS tools (Geographical Information System) it is possible to have maps of pollutants concentrations at ground level (Fig. 2).

Overlapping both concentrations and population maps, it is resulting the impact in terms of μm^{-3} × persons. Also for the macro-pollutants the impact quantification is possible to be done [6] as following:

$$I = A \times \Delta C \times receptor\_population \quad (1)$$

where:

I = *impact*

A = epidemiological studies coefficient
ΔC = variation of the pollutant concentration (input data)
Receptor population = the category on which the impact is assessed

An example in this way is Dokery's function from 1989 [7]. This function gives us like final result the number of cases of chronic chough between the receptor population children as a consequence of a high level concentration of PM_{10} (equation 2).

$$cases\_chronic\_cough = 207 \times \Delta C(PM10) \times children/100000 \tag{2}$$

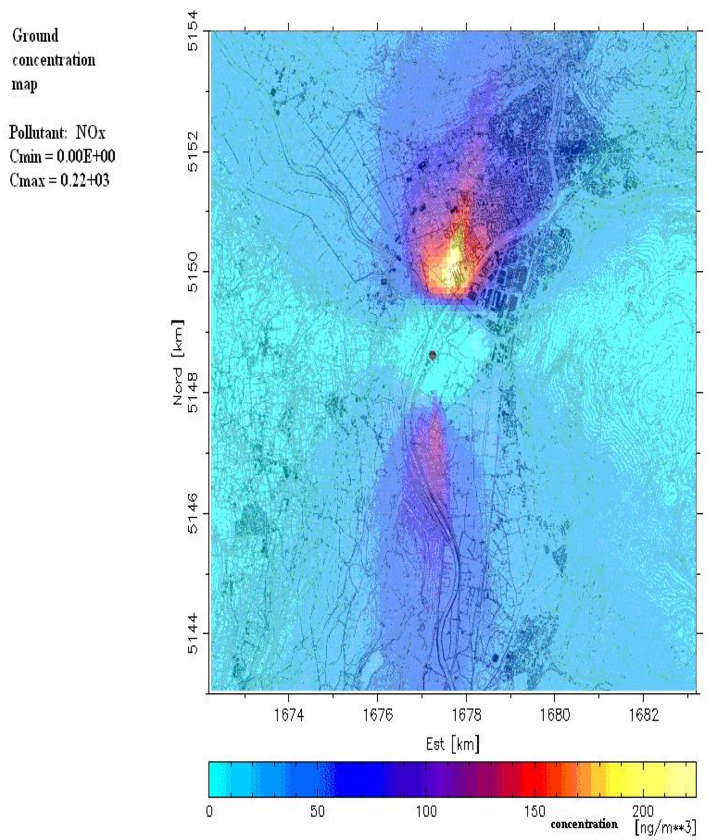

Fig. 2 An example of NOx map concentration from a punctual source (DICA 2003) [5]

6. Thermoelectric and waste incineration plants emissions into atmosphere

Related to the punctual sources of pollutants emissions only recently, the attention has moved to the role of particulate matter. For this reason, some analyses on the particulate impact were made. The particulate is considered primary or secondary as a function of the mechanism of formation with a clear consequence on dimensions: PM_{10} – particles ≤ 10 µm and $PM_{2.5}$ – particles ≤ 2.5 µm respectively. While the primary particulate matter is emitted directly into the atmosphere from a large number of sources, it cannot be said the same about the secondary particulate. This is formed through reactions involving natural sources of the precursors gases (volatile organic compounds, sulphur dioxide, nitrogen oxides and ammonia). For this reason a particular attention must be focused on this type of pollutants. If we want to make a comparison between secondary particulate matter – $PM_{2.5}$ resulted from thermoelectric and waste incineration plants, it is necessary to know which are the estimations related to secondary particulate matter formed into the atmosphere. The main pollutants fraction converted into aerosol is assessed by complex approaches which give useful conversion factors: for instance, according to de Leeuw: 88% for NO_x, 54% for NH_3 and 64% for SO_2 (de Leeuw, 2002) [8]. In order to make this kind of estimations two existing plants with their emissions were considered. It is about a waste incineration plant with a capacity of 94 000 t/year. This plant has a modern flue gas treatment line: fabric filter, scrubber, selective catalytic reduction unit. The yearly average concentrations of particulate matter in flue gas at the stack are about 1-2 mg/Nm^3 with the next average emissions of working plant: SO_2 = 9.3 mg m^{-3} and NOx = 55.8 mg m^{-3} (expressed as dry gas with 11% O_2).

The considered thermoelectric plant has a capacity of 200 MW_{el} and the fuel used is a fossil one. The stack height is about 180 m with a flow gas velocity of 9.45 m s^{-1}. The macro-pollutants emissions resulted from this plant are illustrated in the Table 1.

Table 1

Thermoelectric emissions plants

SO_2	NOx	Particulate matter
[kg h^{-1}]	[kg h^{-1}]	[kg h^{-1}]
114.1	910.0	105.0

Taking into account the secondary particulate matter conversion factors first remembered and the emissions of NOx and SO_2 it was possible to assess the $PM_{2.5}$ formed in one year (Fig. 3).

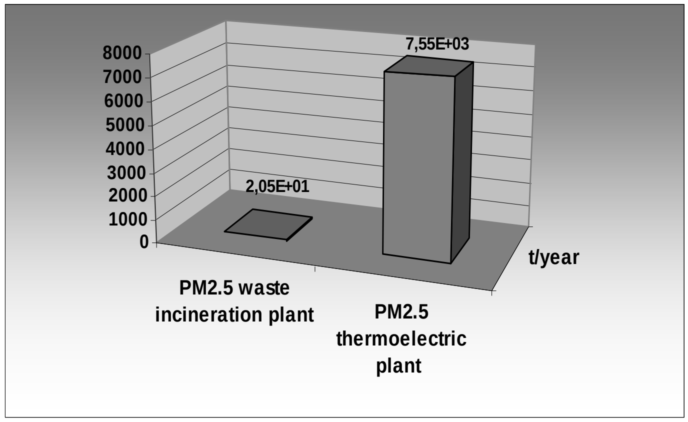

Fig. 3 Secondary particulate matter emissions from the waste incineration and thermoelectric plants

From Fig. 3 is evident the importance of NOx and SO_2 stack emissions removal in order to prevent $PM_{2.5}$ formation (in our case the $PM_{2.5}$ from the thermoelectric plant is two order of size higher than form the waste incineration plant). On the other hand, if we want to evaluate the contribution of the thermoelectric plant in terms of NOx and PM emission to the background level, the European regulation could be considered (1999/30/EC) [9]. From the directive, the yearly limit value for NO_x and PM_{10} is 40 µg/m^3. The yearly average maximum concentrations from the thermoelectric plant are illustrated bellow:

Table 2

Maximum estimated concentrations from the thermoelectric plant (yearly average)

Pollutant	Concentration [µg m^{-3}]
NOx (summer)	100
NOx (winter)	130
TSP (summer)	25
TSP (winter)	25

So, taking into consideration the European regulation and the plant emissions (Table 2), the maximum thermoelectric plant contribution it was possible to evaluate (Fig. 4).

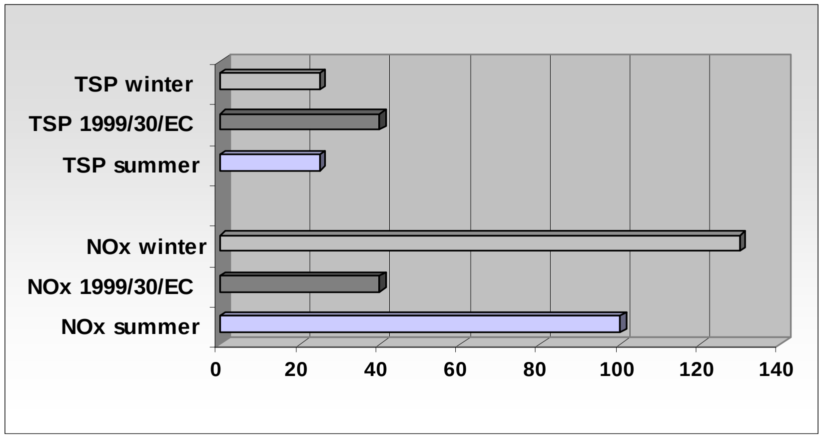

Fig. 4 Comparison between TSP and NOx ambient air concentrations from thermoelectric plant and 1999/30/EC

About the NOx emissions (both for the summer and winter) the maximum emissions are 2.5 and 3.25 times respectively higher than the acceptable air limit concentration. With regard to particulate matter, presuming that all TSP (Total Suspended Particles) is PM_{10}, the plant contribution to the ambient air concentration it is about 62 % both for winter and summer seasons. So, it must be underlined that for a precautionary reason, the PM_{10} was overestimated considering that all TSP is like PM_{10}.

7. Conclusions

1. The present paper is illustrating a theoretical methodology for the human health risk assessment for the thermoelectric plants. In order to apply this methodology at least for the micro-pollutants a software need to be developed. This software is developing now, but in order to be applied in Romania an emissions data base is necessary to be generated. This data base is also essential in order to respect the air emission limit concentrations regulated at the national or European level.

2. For the authorization of a new thermoelectric plant in a territory it is necessary that health effects from the new plant to be overlapped on health effects from the existent ambient air pollutants concentrations. It must be established if the contribution in terms of air pollutants concentration from the new plant is conducting to the ambient air regulated concentration limit overcoming. If the answer is an affirmative one, all the existing pollution sources must be identified and mitigation decisions must be decided in order to be accepted the new thermoelectric plant.

3. For the pollutants emission reduction and consequently a lower human health risk, recommendable solutions are the new investments. These are regarding the conversion of the thermoelectric plants on combustible oil or coal fuel conversion in turbo gas combined cycle plants (TGCC – plants fed by natural gas) or the flue gas cleaning system improving in order to reduce the pollutants emissions. Just in this way it will be possible to reach the air limit concentrations imposed by the European legislation like the Directive 2004/107/CE.

4. For the analyzed thermoelectric plant on coal resulted that the main preoccupation regards the NOx emissions and the secondary particulate matter. Subsequently, it is resulting that for this kind of thermoelectric plants, in order to remove NOx and SO_2, is necessary to invest more with the aim of having lower emission concentrations; as a result minor contribution to the secondary particulate matter formation into the atmosphere.

5. Other aspects that certainly must be considered in the next future for this kind of plants are the micro-pollutants emissions (organic and inorganic). It is definitely sure that an acceptable human health risk cannot be reached if these kinds of emissions are not taken in consideration. It is necessary to quantify their emissions in order to be able to assess the human health risk.

6. For the present paper it was not possible to develop an exemplification of the human health risk assessment methodology for a thermoelectric plant .We hope that in the next future through the existence of a data base this kind of evaluation will be permitted.

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