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ENVIRONMENTAL RISK ASSESSMENT FOR THERMAL POWER PLANTS

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ABSTRACT

Thermal power plants still represent an important source of energy both in Romania and in Europe. Risks on the environment are primarily generated by the noxae generated from combustion of fossil fuels, namely: noxious gases (CO_2, CO, NO_x, SO_x), particulate, heavy metals (As, Cd, Cr, Cu, Ni, Pb), CH_4, polycyclic aromatic hydrocarbons (PAHs), dioxins and furans. All these pollutants plus the slag and the ash resulting from the combustion of fuels have, in time, a significant environmental impact. The environmental hazards caused by these emissions are analyzed in this paper depending on the gravity of the consequences and likelihood of occurrence. It shows the risk analysis, the risk matrix and treating and monitoring to identified risks.

KEYWORDS: hazards, risk analysis, risk matrix, management

1. Introduction

After a several-decade descendant trend, the use of coal for energy is rising again. Coal is still an important energy source in Europe, covering about a quarter of the electricity production [1].

Thermal Power Plants (TPP) are producing electricity by converting thermal energy resulting from the combustion of fossil fuels such as coal, fuel, oil and natural gas. The combustion of fossil fuel in large combustion plants such as those for TPP generate CO_2, present in variable proportions and SO_2, SO_3, NO_X and in smaller quantities heavy metals, halogenated compounds, dioxins and furans [2]. All these pollutants plus the slag and the ash resulting out of fuels combustion have a significant environmental impact in time.

Romania, the same as Germany are on second place in the top of pollution generated by thermal power plants on coal. To reduce the environmental impact, both at European and national level, series of regulations to limit emissions of certain pollutants from these large combustion installations were adopted.

The main pollutants emitted in the air by TPPs are those resulting from the combustion of fuels: huila /lignite and natural gas or fuel oil [3, 4]. The pollutants specific of the combustion in boilers are: noxious gases (CO_2, CO, NO_x, SO_x), particulate matter, heavy metals (As, Cd, Cr, Cu, Ni, Pb), CH_4, polycyclic aromatic hydrocarbons (PAHs), dioxins and furans [5].

The most likely way of transfer of the pollutants to receptors is through air, an environmental factor that favors a fast transport and direct contamination by inhalation. In this manner, employees are affected by pollutants present in the atmosphere of the workplace, from diffuse sources and in high concentrations. Also in this way, the population and ecosystems in the vicinity of TPP come in contact with gaseous and particulate pollutants specific to the processes, resulting out of controlled sources and diffuse sources, but in smaller concentrations, after having undergone a prior dilution in the atmosphere.

The main sources of *air pollution* are:

- emissions of SO_2, NO_x, particulates and CO_2;

- coal dust originated from the deposits solid fuel (coal), which has an action zonal;

- dust arising from deposits (dumps) of ash and slag through deflation, when these particles are shattered by the wind and entrained into the atmosphere.

The pollutants emissions (E) are influenced by the quality of fuels (coal, fuel oil, natural gas).

The methodology for calculating the quantity of those emissions is based on fuel consumption (B), caloric power of the fuel (C) and emission factors (e) [2]:

$$E[Kg] = B \times C \times e \quad (1)$$

The water required for the technological steam production in thermal circuit of the TPP and for fires extinguishing is collected and treated (softened, demineralized and deferrized).

The rainwater polluted with oil products resulting from the site of the fuel oil deposit are collected through the sewage system and transported to an oil separator then discharged in the pluvial and technological drainage system.

The soil can be affected by deposition of particulates and action of heavy metals resulting out of combustion of coal. The main waste materials derived from the combustion of fuels solid (coal) at the TPPs are the slag (15%) and the ash (85%) [5].

The slag-ash mixture, coming from electrofilters and water is called hydro-mixture and it is discharged into specially designed storage (dump).

Slag-ash dumps cause pollution of the atmosphere and soil through slag-ash drifting. Soil monitoring is performed periodically (usually annually).

2. Environmental risk assessment

2.1. Analysis of the impact on the environment

Water pollution [6], air pollution and disposal of wastes have a significant impact on biotic factors. The dispersion in atmosphere of CO_2, SO_2, of particulates [7] and toxic VOCs and the dissolving in water and passing in soil of pollutants is a permanent source of risk to living organisms.

The particulate matter resulted from the coal deposit and into processes or the dust shattered on the slag dump may reduce the intensity of the chlorophyll assimilation by reducing light radiation. Depositions of suspensions on leaves is causing the stomata blockage affecting photosynthesis and plant regime of gas exchange with effects such as: reducing the rate of development, lower production and decreased quality of production. Dusts with content of heavy metals can indirectly affect plants growth by depositing on soil which modifies the nutrients transformation processes of the plants.

Sulfur oxides emitted to the atmosphere come in contact with rain water resulting in acid rain (dilute solution of sulfuric acid and sulfur dioxide) that cause adverse effects [2, 5] on the environment, such as:

- vegetation damage, especially of the coniferous forests, through direct destruction of chlorophyll;
- acidification of soils and deficiencies in plant nutrition by dissolving the salts of calcium and magnesium in the soil;
- dissolving of the waxy protective layer of the leaves, the plants becoming less resistant to pests;
- over-fertilizing the soil resulting in premature accelerated of plants growth;
- acidification of lakes and damage ichtyofauna.

Depending on the degree of exposure, SO_2 can lead to physiological and biochemical effects such as: reducing photosynthesis, chlorophyll degradation, changes in the metabolism of proteins, lipids and enzyme balance activity. These effects translate into necrosis, plant growth reduction, increased susceptibility to various pathogens and at the severe climatic conditions.

Sulphur oxides have negative effects on human health, causing irritation or respiratory problems [8].

Polycyclic aromatic hydrocarbons (PAHs) are carcinogenic at long exposure time, even at very low concentrations. Short-term exposures to PAHs may cause skin and upper respiratory tract irritation, dizziness, nausea, headaches, weakness. Very high doses can lead to respiratory collapse and liver damage, damage of lungs, kidneys and blood system. Long-term exposure can also lead to cancer and damage of the liver, kidneys, lungs and blood and lymph systems. The simultaneous presence of SO_2 exacerbates these effects.

The forming of nitrogen oxides the fuels combustion and in function of combustion conditions NO or NO_2 may result. NO quickly turns into NO_2 in the atmosphere, a gas with irritating smell and strong oxidant. NO_2 is a precursor to ozone forming. By reaction with the water in the atmosphere, a portion of the NO_2 is converted into nitric acid (HNO_2 and HNO_3). In urban areas these acids are combined with ammonia to form ammonium nitrate (NH_4NO_3). Ammonium nitrate is found as aerosols contributed significantly to pollution of urban areas with particulate matter (having dimensions of 2.5-10 μm).

Human health is affected directly by nitrogen oxides through exposure to NO_x and indirectly through the formation of secondary pollutants such as ozone and the atmospheric aerosols contributing to photochemical mist and particulate matter [8, 9]. Nitrogen oxides (NO_x) have a beneficial effect on the plants up to a certain concentrations contributing to plants growth. Over toxic thresholds NO_x has a clear phytotoxic action, such as reducing photosynthesis and transpiration, chlorosis and necrosis. NO_x and SO_2 have a synergistic effect on the plants, only these two pollutants or in combination with the ozone. The effects of acidic rainwater containing NO_x and SO_2 may affect plants and ecosystems situated at a great distance from the emission source.

Ozone (O_3) is formed in the atmosphere by photochemical reaction of NO_x and solar radiation, favored by a wide spectrum of volatile organic compounds (VOCs) into the atmosphere. Both pollutants, NO_x and VOCs, are specific of combustion processes, so it is expected that ozone to be present in the atmosphere in the vicinity and inside thermal power plants. Ozone is a strong oxidant and therefore can react with each class of biological substances. Long-term exposure leads to chronic diseases of the upper respiratory tract and ischemic heart disease [10]. Ozone affects crop plants and trees, especially species that have a long growth / development cycle, causing visible alterations as defoliation and foliage changes. It can have effects both on plant species and on biodiversity of ecosystems natural.

Volatile organic compounds (VOC) are pollutants commonly found in any combustion process, as a result of incomplete combustion. The effects of these compounds on human health are related to their presence in the atmosphere in natural state or transformed. These are substances with high toxicity and potential risk of cancer.

Dioxins and furans - PCDD / F are organic compounds unintentionally produced in very low concentrations in emissions or in products of some processes. They have very high and variable toxicity with a potential hazard to the environment and people. Main emission source is represented by the combustion processes. To evaluate the toxicity of these substances the European reference standards recommended the toxic equivalent (TEQ) [11, 12]. This value is used to evaluate the health risk of those exposed to these emissions. Numerous harmful effects of dioxins and furans on human health have been demonstrated. These are characterized as destructive substances for the endocrine system, causing fertility problems, pregnancy problems and even infertility.

Water pollutants (phenols, ammonia, heavy metals, petroleum products) can affect the life and activity of aquatic ecosystems, having the effect of a quantitative reduction [13].

Radioactivity. The main source of radioactivity is coal, which may contain: U-238, Th-232 and K-40 [6]. By the burning of coals, the natural radioactive substances present in their composition are concentrating in slag and ash, and radioactivity increases. Even if the amount of radioactive elements is large, considering that the distribution in the slag dump is homogeneous, the effect of irradiation "in situ" is not usually higher than the allowable limits. The radiological risk should not be ignored; the cumulative effects can be adverse on biotic factors.

The noise. In relation to the frequency, duration, moment of production of the different noises and propagation conditions (wind direction) employees and neighboring populations may be affected. Among the frequent manifestations due to noise exposure, hearing fatigue, hearing loss and professional deafness are included.

2.2. Analysis of identified environmental hazards

The flammable materials used or resulted from processes, the toxic or corrosive materials, handled, used or generated in processes, diffuse emissions, action cumulative and synergistic of the pollutants and the noise of installations and of the aggregates, can create problems for the personnel safety and environment.

In a thermal power plant, places with high pollution potential (risk) are:

- the chemical treatment station;
- the boilers-steam power station;
- the solid fuel station.

Principal risk factors are:

- chemical risk factors (CO, CO_2, SO_2, VOC, dioxins and furans);
- physical risk factors: noise, microclimate, radioactivity, electric and magnetic fields;
- physico-chemical pollutants: diverse particulate (coal dust, slag, ash).

The usage of fuels (coal, gas, fuel oil, diesel, coal dust) has a high potential risk of fire and explosion, and poisoning with CO.

Potential hazards for environmental factors are:

P1 - the emission, transport and dispersion of SO_2 in the air over the accepted norms;

P2 - the emergence of acid rain caused by SO_2, SO_3 by reaction with rainwater;

P3 - CO_2 emissions with major influence on climate change;

P4 - NO_x emissions over the accepted norms;

P5 - formation, due to NO_2, of the nitric acid and the ammonium nitrate aerosols;

P6 - formation of the ozone; having as precursor of NO_2;

P7 - emissions diffuse / fugitive of CO;

P8 - emissions diffuse / fugitive of dioxins and furans;

P9 - soil pollution in the slag dump;

P10 - Soil pollution by coal dust in the storage of raw materials;

P11 - Soil pollution by oil products;

P12 - pollution of groundwater;

P13 - pollution by wastewater;

P14 - fly ash;

P15 - slag and ash particles shattered of the air currents;

P16 - radioactive slag and ash;

P17 - transfer and dispersion of pollutants in aquatic environments;

P18 - noise pollution;

P19 - production of the fires;

P20 - production of the explosions.

2.3. Risk Analysis

Considering the high impact of the pollutants on the environment, a matrix of the type shown in Table 1 was chosen for the environmental risk assessment.

As shown in the risk matrix, there is a large number of hazards, with medium and high risk, requiring reduction measures. The low risks will be monitored so that they remain in this class of risk.

Table 1. *Risk Matrix*

Likelihood	Low impact	Medium impact	High impact
Not very likely (<10%)	-	-	risk less (P17)
Less likely (<35%)	-	-	risk medium (P7, P8, P12, P13, P20, P19)
Can or not can happen (35%-65%)	-	risk medium (P5, P6, P11)	risk high (P2)
Fairly likely (>65%)	risk less (P4)	-	risk high (P1, P14, P15)
Very likely (>90%)		risk medium / high (P3, P9, P10, P18)	risk high (P16)

2.4. Treatment and monitoring of the risks

In order to ensure adequate health and safety conditions of work in the energy system and to improve the environmental performance, it is necessary to take organizational and technological measures. Management measures will be implemented for labor discipline and measures that lead to the operation of installations under appropriate conditions, especially the sealing of the possibly pollutant-generating equipment. Taking some technical measures will be equally important, i.e. by introducing facilities or equipment that lead to reducing emissions under a maximum admissible or that would create the possibility of conducting activities outside the noxious environment.

To reduce the environmental impact of the identified risks, many measures starting from the management ones to the technical and technological solutions should be considered, such as:

•control of combustion processes that are the main generating sources of pollutants;

• improvement of ventilation in all indoor spaces;

• modernization of the electro filters;

• use of the desulphurization installations of the latest generation;

• burning fuel with low content of ash, sulfur etc.;

• use of facilities for monitoring of gaseous emissions;

• wetting the dry areas of the dumps.

Monitoring emissions can be done through a system of monitoring and measuring of the gaseous components at the chimney exit to determine the concentrations of SO2, NOx and dust. It is also necessary to measure the relevant process parameters of the fuel burning respectively: % O_2, temperature, pressure, humidity and flue gas flow to the chimney.

3. Conclusions

- Fossil fuel combustion in thermal power plants generates large amounts of CO_2 and in varying proportions SO_2, SO_3, NO_x, heavy metals, halogenated compounds, dioxins and furans, slag and ash, that have a significant impact on the environment.
- Most of the identified dangers in the risk analysis are included in medium and high risk classes.
- The below have an impact with high risk on the environment:

- CO_2 emissions with major influence on climate change;

- the slag and ash particles shattered of the air currents from the dump and depositing them on soil and vegetation or inhaled by humans and animals;

- radioactive slag and ash;

- formation of the nitric acid and the ammonium nitrate aerosols due to NO_2;

- the emergence of acid rain caused by SO_2, SO_3 by reaction with rainwater;

- formation of the ozone; having as precursor of NO_2;

- To reduce the environmental impact of the identified risks, measures can be taken from managerial to technical measures and even closing these plants through larger scale usage of renewable energies.

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