PlasTEP

plasma for environment protection

List of potential processes suitable for plasma technologies application

PREPARED BY PLASTEP PARTNER #11 INSTITUTE OF NUCLEAR CHEMISTRY AND TECHNOLOGY

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1 Introduction

Apart of numerous advantages, the development of technical civilization causes environmental pollution. Some substances released into the environment, such as heavy metals and some organic compounds, are highly toxic, while the others are responsible for damages in environment and human health in longer periods. Regardless the pollutant type and effects of its release into the environment, all of them are a subject of monitoring and emission control.

Every technological process consists of three basic steps: acquisition of raw material, raw material preparation and the basic technological process. The integral part of any technological process is system of outlet streams purification especially gaseous and liquid wastes. However every technological process has its impact on various fields of natural environment. Figure 1 presents the scheme of environmental impact of conventional power plants.

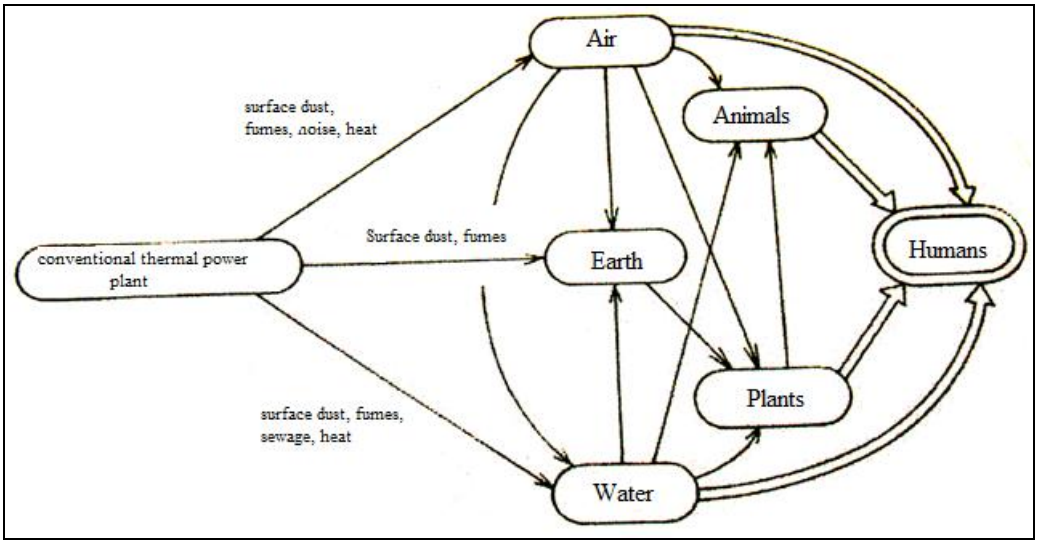

Figure 1. The impact of conventional power plants on the environment.

The emission depends on the raw material used in the process, type of technology and efficiency of equipment for the exhaust gases purification. Based on knowledge of composition of the raw materials one can predict the volume emission and composition of released pollutants. Also technological process used in the production has a significant impact on the size and composition of emission. Another important problem is

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pollutants' propagation that depends on concentration of industrial plants, geography and topography of region, meteorological conditions, local climate conditions.

The fact of transportation of pollutants across the borders of individual states is undeniable. Therefore economic responsibility for the pollutants emitted into the atmosphere and connection of economic development with permissible limits emission for specific regions is necessary. These limits must be selected in a way not leading to accumulation of pollutants that might destroy the ecosystem self-cleaning ability.

Solution of the problem of atmospheric pollution over the Baltic Sea area requires the cooperation of all countries of this region. The integrating role in the initiation of comprehensive research to solve problems pollution in Baltic Sea Region was played by PlasTEP project. The project, oriented on dissemination of the knowledge of plasma technologies and their environmental applications, brings together 15 partners from 8 countries (See Figure 2).

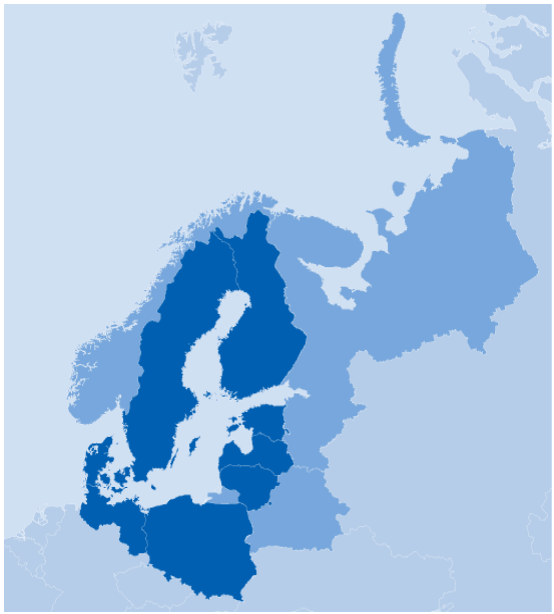

Figure 2. Baltic Sea Region (BSR).

The main point of the PlasTEP project is to clearly inform the decision makers from politics and economy about the practical possibilities of the low-temperature plasma technology for environmental purposes to establish a market driven transfer process and an increasing number of applications. This elaboration is realized in frame of PlasTEP project.

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2 Plasma technologies for NO_x, SO_2 and VOC emission control

The European Union over the next 20 years will promote and support the implementation of competing technologies for reducing emissions of SO_x and NO_x in power plants. This policy is reflected both in the declarations, the relevant legal provisions as well as funds for research and implementation. Emission policy of the European Union is a major challenge for many countries. Implementation of this policy in accordance with current recommendations and presaged restrictions will cause a significant economic load. Classic power plants based on coal or lignite will be loaded with high costs of emission permits. Expected increase of price for electricity can offset the costs of introducing new technologies.

Energy sector based on the conventional exhaust gases cleaning still plays a dominant role despite of continuous development so-called "environmentally friendly" plasma technologies. Most of the currently constructed or planned power plants in the world will be powered by coal, and regulations adopted within the European Union (Directive dated 07/07/2010) require dramatic reductions in emissions of nitrogen oxides by 2016, which intensifies research on the innovative technologies. At the moment plasma based technologies of emission control are one of the most promising.

Non-thermal plasma used in the environmental protection processes has numerous advantages. Most important is the lack of side effects and waste products (which are harmful to the environment), and the ability to carry out the process at atmospheric pressure and ambient temperature.

Non-thermal plasma technology allows on simultaneous removal of SO_2 and NOx, in the same process with high efficiency. In addition, one of the methods (EBFGT) gives opportunity to agricultural use of by-product generated in the process that makes it wasteless. An additional advantage of this method is that in the same process other pollutants such as volatile organic compounds, dioxins, acid impurities (HCl, HF, SO_3) and others are also removed.

The biggest advantage of plasma technology is its flexibility. Due to simple construction of facility, the installation can be easily adjusted to the various parameters of gas stream.

There are known different plasma technologies for emission control. Summary of the most popular plasma technologies and dedicated applications are shown in table 1.

Table 1. Summary of the most popular plasma technologies.

Type of plasma technology	Applications	Manner of power supply
Dielectric-Barrier Discharges Reactors	Ozone synthesis, methane conversion	Alternating current mains frequency and increased

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– DBDs		
Dielectric Bed Packted Reactors	SO_x and NO_x removal, hydrocarbons conversion	Direct, pulse and alternating voltage
Corona Reactors	Dust filtration, ozone generation	Pulse, direct voltage
Hollow Cathode Discharges Reactors	Sterilization, organic materials treatment	Pulse voltage, high frequency
Surface Discharge Reactors	Removal of NO_x and volatile organic compounds	Sinusoidal voltage of elevated and high frequency
Arc Reactors (plasmatrons)	Chemical synthesis, melting, welding, surface treatment	Direct voltage, unidirectional, sinusoidal voltage of mains frequency
EBFGT (Electron Beam Flue Gas Treatment)	Removal of SO_x and NO_x. Removal of volatile organic compounds (VOCs)	Constant, pulse and alternating voltage
Quasi-Arc Reactors (with gliding arc)	Hazardous gases neutralization, removal of SO_x and NO_x	Direct, pulse and alternating voltage
Microwave Reactors	Removal of volatile organic compounds	Voltage with a frequency of the order of mega and giga hertz

3 Emission structure in Baltic Sea Region

Due to PlasTEP project assumptions, the following countries of Baltic Sea Region were concerned: Finland, Estonia, Latvia, Lithuania, Poland, north Germany, Denmark and Sweden. According to the total emission of SO_2 and NO_x these countries may be divided into two groups: Lithuania, Latvia, Estonia and Northern Germany as one group and Poland, Finland, Sweden and Denmark in other group of countries.

In the first group of countries, in 2008, NO_x emissions varied from 6,190 to 67,739 t/year and SO_2 emissions varied from 842 to 69,333 t/year, while in the second group of countries NO_x emissions varied from 151,686 to over an 831,000 t/year and SO_2 emissions varied approximately from 20,000 to 998,561 t/year. The highest NO_x emissions in Baltic States are released in Lithuania (67,739 t/year), however, the highest SO_2 emissions are reported in Estonia (69,333 t/year). In the other group, the highest emissions of all concerned air pollutants were reported in Poland (NO_x – 831,225 t/year; 998,561 t/year of SO_2). The NO_x emissions in Scandinavian countries are similar (151,686; 154,403 and 165,877 t/year). Meanwhile, the highest SO_2

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emissions were reported in Finland (173,025 t/year). However the highest emission is noticed in the largest countries.

In the case of VOC emission, the highest is recorded in Poland (582,623 t/year). Among the first group of countries the highest emission was noticed in Lithuania (71,465 t/year).

The emission per capita shows different point of view (Table 2).

Table 1. Annual SO_2 and NO_x emissions per capita in Baltic Sea region countries.

Country	Emission kg/year		
	SO_2	NO_x	VOC
Finland	13	31	22
Estonia	52	26	26
Latvia	1	17	24
Lithuania	9	20	21
Poland	26	22	15
north Germany	0.5	3.6	1.8
Denmark	4	28	19
Sweden	3	16	18
Average	22.8	15.4	18.4

Total emission per capita in eight BSR countries is similar in the case of NO_x and VOC. In case of SO_2 two countries (Estonia and Poland) are considerably above average. North Germany reports very low emission in both cases, however in this case it is the only case, that only low industrialised part of country is regarded.

The highest source of emission in all the concerned countries is energy and heat generation. This is also a reason of high SO_2 emission in Poland and Estonia, that use respectively coal and oil shale as main source of energy. As the second source, metallurgical industry shall be mentioned. The emission from other industrial processes as cement production, chemical industry and others, is also connected mostly with combustion processes. It shall be noticed relatively high emission from mobile sources (transport), especially in the case of nitrogen oxides.

Among the other sources of emission the municipal and housing sector heat generation shall be mentioned. This kind of emission is especially hard for control due to distribution of large number of small emitters In the large area.

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4 Potential plasma technologies application for pollution control

The emission structure in BSR points the main areas of potential plasma based emission control technologies application.

1. Combustion processes

The processes based on the fuels combustion are the most important potential users of plasma based emission control technologies. Among the others the following combustion processes shall be mentioned:

Energy and heat generation

Oil refineries

Waste incinerators (municipal and medical)

Cement and concrete production

Metal production (ore sintering)

And others.

The flow rate of flue gases from theses processes are mostly of few hundred m^3/h. At the moment only one plasma emission control technology has been applied for such large gas streams – electron beam flue gas treatment. However, after development, the other technologies may also be adopted for this scale.

2. Transport

Two main categories of mobile emission sources suitable for application of plasma emission control technologies shall be mentioned:

Road transport (trucks)

Sea transport (vessels)

In this case the potential technologies are to be light, flexible and simple in construction and operation. Such criteria are easily fulfilled by DBD reactors and successful attempts of application of this technology for mobile sources has been noticed.

3. Industry

Most plasma technologies applied in the industry are strictly connected with production as surface treatment technologies. However industrial processes other then fuels combustion, are also a source of harmful pollutants emission. Plasma emission control technologies may be applied in such processes as:

Fertilizer production

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Minerals production

Chemical industry

Solvent releasing processes (surface treatment and other chemical processes)

And others

Due to large variety of industrial processes, different plasma emission control technologies may be applied.

4. Odour generating processes

Odours are the serious problems of numerous plants of such areas as:

Food production

Waste disposal

Wastewater treatment

As the concentration of odorous compounds are relatively low, conventional emission control technologies are not sufficient. Application of plasma technologies is promising solution in this case. Application of plasma for odour removal has been demonstrated within the PlasTEP project.

5 Conclusions

Removal of pollutants by conventional methods requires the use of complicated installations combining various methods of pollutants treatment. Application of plasma based emission control technologies is a promising solution for multicomponent treatment of flue gases. Different plasma technologies may be applied for treatment of flue gas from such processes as combustion of fossil fuels, road and sea transport, various branches of industry or processes generating odours. Due to high flexibility and variety of plasma based technologies, they might be adopted for different processes and different composition of treated gases. However due to dispersion of emission sources in municipal sector, the possible application of plasma based technologies shall be sought in industrial sector.

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