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CIGARETTE SMOKE OR EXHAUST GAS FROM WASTE INCINERATION – WHERE ARE MORE DIOXINS?

Abstract
In Poland, incineration is a relatively new method of waste treatment. Modern installations for waste incineration have two functions: they reduce the quantity (volume) of the waste and are a source of electricity and/or heat. During all combustion processes including waste incineration, polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCD/Fs) (well known as dioxins) are formed. These compounds are considered to be extremely dangerous for living organisms including human beings.

Dioxins are formed in any process of combustion of solid and liquid fuels in the presence of chlorine, oxygen and organic matter at appropriate temperatures. Combustion processes also occur during cigarette smoking, which is also a source of dioxin emissions. Although smoking has been classified as a less important source of dioxins in the environment, it directly affects our health.

This work's aim is to determine and compare the degree of harmfulness caused by the amount of inhaled dioxins: cigarette smoking or living near a waste incineration plant.

Based on literature and experimental data, the concentration of dioxins in cigarette smoke and exhaust gases generated by municipal waste incineration plants as well as number of dioxins absorbed per day by the body will be presented.

Key words
polychlorinated dibenzo-p-dioxins, combustion, incineration plant, cigarettes

Introduction

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), known in short as dioxins and furans, are widely regarded as one of the most dangerous environmental poisons.

The general name of dioxins usually covers the entire group of chemical compounds including 75 polychlorinated dibenzo-p-dioxins and 135 polychlorinated dibenzofurans, chemical compounds with the general formula shown in Figure 1. The dibenzo-p-dioxin molecule has two axes of symmetry, while the dibenzofuran molecule has one axis of symmetry, which explains significant differences in the number of congeners [1-3].

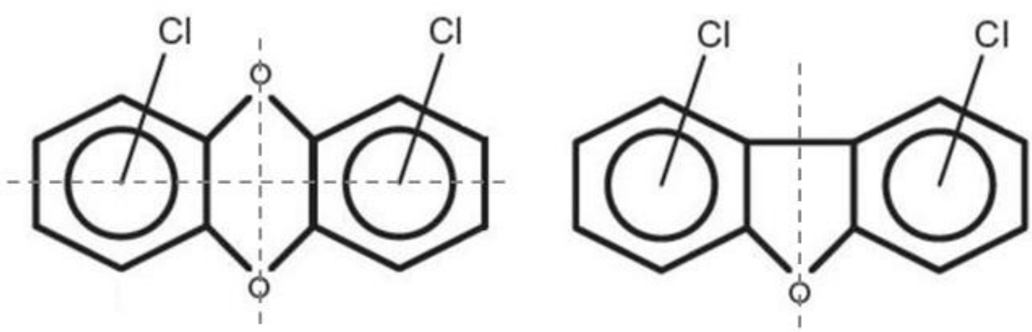

Fig. 1. Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans
Author's own source

A common feature of all dioxins and dioxin-like chemicals is their high melting point, low volatility and very good solubility in fats and hydrophobic solvents, with very low solubility in water [4-5].

Dioxins and furans are formed as an undesirable by-product in all combustion processes (including incineration of municipal, industrial and medical waste and sewage sludge as well as during the combustion of fossil fuels, in particular, hard coal, lignite and biomass) also in some industrial processes such as the production of pesticides, paper and cellulose, as well as in the iron and steel industry and in the production of non-ferrous metals.

The concentration of dioxins from municipal waste incineration plants in the flue gas stream is usually from 0.001 to 50 ng TEQ/m^3, depending on the exhaust gas treatment system [6-8]. Of course, the highest concentrations occur when there are no exhaust gas treatment systems. In the case of tests of dioxin emissions from industrial incinerators, results obtained were at a similar level as for municipal waste incineration plants [9-10]. For medical waste incineration plants, dioxin concentrations in the exhaust gases are slightly higher than for municipal waste incineration plants, which most probably results from simpler and less efficient exhaust gas treatment systems and high content of chlorine and chlorinated compounds in the incinerated waste [11-12].

Combustion of fuels in small domestic furnaces differs significantly from the combustion of the same fuels in large energy facilities. Usually, in small domestic furnaces, the oxygenation of the combustion zone is insufficient and, as a result, incomplete combustion occurs. This is manifested by increased emissions of carbon monoxide and organic micro-pollutants. The emission of dioxins from small furnaces may be low – concentrations in the emitter reaching 0.01-0.08 ng TEQ/m^3 [13], in other – slightly higher 0.03-1.2 ng TEQ/m^3 [14], and even 0.1-40 ng TEQ/m^3 [15], while in the case of fireplaces, concentrations exceeding even 20 ng TEQ/m^3 were observed [16].

The combustion processes during which dioxins and furans are formed also include cigarette smoking. Dioxin concentrations in the cigarette smoke can reach up to 2 ng TEQ/m^3, i.e. at least 20 times higher than the permissible concentrations of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/Fs) in exhaust gases from waste incineration plants [17]. Considering the large scale and widespread cigarette smoking, dioxin emissions from this source on the world scale can be significant.

Despite the very high toxicity of some dioxins and furans concerning certain animal organisms, it is difficult to compare them with other strong poisons present in the environment, because their action is not immediate at concentrations we encounter every day. The harmful effect of PCDD/Fs lies mainly in disturbing the endocrine function of the body, resulting in impaired fertility, problems with maintaining a pregnancy or even infertility [18]. This is primarily a disturbance of secretion of progesterone, a hormone necessary for the maintenance and proper course of pregnancy [19]. However, there is no scientific evidence that dioxins have carcinogenic properties [20-21]. Some health effects resulting from the long-lasting effects of low concentrations of PCCD/Fs include decreased immune system activity, disturbed psychomotor development of children, thyroid hormone dysfunction, decrease in the amount and quality of sperm and increased number of cases of ovarian cysts [22].

Research and results

Based on literature and mentioned above experimental data, it was decided to compare the concentrations of dioxins in cigarette smoke, exhaust gases produced during combustion of so-called refuse-derived fuel (RDF) and flue gas streams from domestic coal-fired boilers. The a number of dioxins absorbed per day in the body from the previously mentioned 3 sources was also compared.

The concentration of toxic substances in cigarette smoke is affected by the oxy-temperature conditions of the smoke produced. These conditions depend on the way of smoking a cigarette, i.e. on the so-called smoking topography. Based on the literature data [23-26], the following parameters of the topography of smoking were adopted (Table 1).

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Table 1. Parameters of smoking topography

Parameter	Value
Puff volume	60 ml
Concentration of dioxins in cigarette smoke	2 ng/m^3
Time of smoking 1 cigarette	5 min
Number of puffs when smoking 1 cigarette	20
Number of cigarettes in one pack	20

Source: Author's

The calculations were made according to the following as Equations 1 and 2:
Amount of dioxins from smoking one cigarette:

$$E_{p1} = z \cdot V \cdot c_d \tag{1}$$

where: z - number of puffs when smoking 1 cigarette
V - puff volume
c_d - concentration of dioxins in cigarette smoke

Amount of dioxins from smoking one pack of cigarettes:

$$E_{p2} = E_{p1} \cdot n \tag{2}$$

where: n - number of cigarettes in one pack
When calculating the dioxin emissions from smoking from eq. (1) and (2) the dioxin emissions from smoking one cigarette (E_{p1}) is 0.0024 ng and from smoking one cigarette pack (E_{p2}) is 0.048 ng.

The amount of dioxin emissions and then the immission from waste incineration plants fired refuse derived fuel (RDF) was calculated for an example of a municipal waste incineration plant with a capacity of approx. 94,000 Mg/year. The concentration of dioxins in the flue gas stream taken for calculations was equal to 0.025 ng/m^3 [27-30]. This is the size typical for this incineration plant confirmed in several emission tests. For domestic coal-fired boilers, dioxin concentration of 9.2 ng/m^3 was adopted according to literature data [31-32]. Detailed data accepted for calculations are presented in Table 2.

Table 2. Input values used in the calculations

Parameter	Symbol	RDF incineration plant	Domestic coal-fired boiler
Fuel calorific value	w_D	7 000 kJ/kg	19 000 kJ/kg
Maximum fuel consumption	$B_{\max}$	11 750 kg/h	50 kg/h
Excess air coefficient	λ	2.1	1.9
Dampness of flue gases	$[H_2O]$	10%	5%
Exhaust gas temperature	t	200°C	120°C
Concentration of dioxins in the smoke under conventional conditions	c_D	0.025 ng/m$_u^3$	9.2 ng/m$_u^3$
Concentration of sulfur dioxide in the exhaust gas	c_{SO2}	50 kg/h	2 000 kg/h
Concentration of nitrogen oxides in the exhaust gas	c_{NOx}	200 kg/h	600 kg/h
Emitter height	*H*	60 m	7 m
Emitter diameter	*D*	1.8 m	0.25 m
Gas flow rate in the emitter	*u*	12.3 m/s	4.2 m/s

Source: Author's

The scheme of emission calculation [33] and summary of results (Table 3) are presented below.
Theoretical air demand:

$$V_T = \frac{0.241 \cdot w_D}{1000} + 0,5 \tag{3}$$

The amount of exhaust gases generated at complete combustion:

$$V_P = \frac{0.212 \cdot w_D}{1000} + 1,65 \tag{4}$$

The indicator of the amount of generated flue gases:

$$V_C = V_P + (\lambda - 1) \cdot V_T \tag{5}$$

Flue gas stream under normal conditions:

$$V_N = B_{\max} \cdot V_C \tag{6}$$

Oxygen concentration in the exhaust gas:

$$C_{O_2} = \frac{(\lambda - 1) \cdot B \cdot V_T \cdot 21\%}{V_N} \tag{7}$$

Flue gas stream in real conditions:

$$V = V_N \cdot \frac{273 + t}{273} \tag{8}$$

Flue gas stream under conventional conditions:

$$V_u = V \cdot \frac{21 - [O_2]_{rzecz}}{21 - [O_2]_u} \cdot \frac{100 - [H_2O]}{100} \tag{9}$$

where: $[O_2]_{rzecz}$ - actual oxygen concentration in the exhaust gas

$[O_2]_u$ - oxygen concentration in conventional conditions (11% for waste incineration plant, 6% for coal combustion)

Maximum dioxin emission:

$$E_D = V_u \cdot c_D \tag{10}$$

Maximum emission of sulfur dioxide:

$$E_{SO2} = V_u \cdot c_{SO2} \tag{11}$$

Maximum emission of nitrogen oxides:

$$E_{NOx} = V_u \cdot c_{NOx} \tag{12}$$

Table 3. Results of emission calculations for RDF incinerators and domestic coal-fired boiler

Parameter	Symbol	RDF incinerator	Domestic coal-fired boiler
Theoretical air demand	V_T	2.187 m^3/kg	5.079 m^3/kg
Amount of exhaust gases generated at complete combustion	V_P	3.134 m^3/kg	5.678 m^3/kg
Indicator of the amount of generated flue gases	V_C	5.540 m^3/kg	10.249 m^3/kg
Flue gas stream under normal conditions	V_N	65 097 m$_N^3$/kg	512 m$_N^3$/kg
Oxygen concentration in the exhaust gas	C_{O_2}	9.12%	9.37%
Flue gas stream in real conditions	V	112 778 m^3/h	738 m^3/h
Flue gas stream under conventional conditions	V_u	19 450 m$_u^3$/h	160 m$_u^3$/h
Maximum emission of sulfur dioxide	E_{SO2}	0.972 kg/h	0.321 kg/h
Maximum emission of nitrogen oxides	E_{NOx}	3.890 kg/h	0.096 kg/h
Maximum emission of dioxins	E_D	0.486 µg/h	2.212 µg/h

Source: Author's

The presented data illustrate the number of dioxins in the flue gas stream. In the case of waste incineration plant, the introduction of exhaust gases into the environment takes place at a height of about 60 m above the earth's surface. For a domestic coal-fired boiler, the emitter is about 7 m above the earth's surface. When smoking cigarettes, the emitter (cigarette) is at the level of our lips, so there is a direct absorption of pollutants from cigarette smoke. Analyzing the phenomenon of spreading pollutants from the incineration plant and basing on calculations according to the Pasquill model made in the OPA03 program, it can be assumed that the concentrations of pollutants at the earth's surface are about 10^{11} times lower than the concentrations of pollutants in the exhaust gas stream in the RDF incinerator and around 10^{13} times smaller than in a domestic coal-fired boiler [34-36].

To determine the immission of dioxins during cigarette smoking, it was assumed that the volume of one breath is about 0.5 dm^3, the number of breaths per minute 16, and thus the volume of air inhaled per hour is 480 dm^3. The table below presents the values of dioxin immission inhaled by man from individual sources.

Table 4. The amount of dioxins inhaled by a human

Source	Value
Cigarette smoking	$4.8 \cdot 10^{-2}$ ng/pack
	$2.40 \cdot 10^{-3}$ ng/cigarette
Coal-fired boiler	$1.00 \cdot 10^{-4}$ ng/h
Waste incineration plant	$2.30 \cdot 10^{-3}$ ng/h

Source: Author's

For the RDF waste incineration plant and coal-fired boiler, the highest concentrations observed near the earth's surface at a distance of approx. 200-300 m from the emitter was assumed, which resulted from the calculations.

Summary and conclusions

Waste incineration is one of the best ways of its neutralization. Waste incineration plants practically do not have a negative impact on water and soil, which is a great advantage compared to a landfill. The volume of waste generated is also significantly reduced, and modern technologies make it possible to utilize combustion residues. However experience shows that such investments do not meet a positive reception in society. Each project of building a waste incineration plant instigates social protests. In general opinion waste incineration plants cause very severe pollution of the environment. This is mainly due to the lack of information in society. Based on the analysis, it can be unequivocally stated that a man absorbs 0.0024 ng of dioxins while smoking one cigarette. During one working hour, the incinerator generates as many dioxins as it is produced during smoking of one cigarette. On the other hand, in the case of one-hour work of a domestic coal-fired boiler, one inhales as many dioxins as there are in 0.045 cigarette, in other words smoking 1 cigarette is equivalent to about 24 hours of exposure to the emission range from an old type coal-fired boiler. At the same time, it should be remembered that cigarette smoke contains significant quantities of highly toxic substances, including carcinogenic substances, such as benzo(a)pyrene, hence its harmfulness for the human body is many times higher [21].

Conflict of interest
There are no conflicts to declare.

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