ARCHIVES OF ENVIRONMENTAL PROTECTION
ARCHIWUM OCHRONY ŚRODOWISKA
vol. 33 no. 4 pp. 83 - 95 2007
PL ISSN 0324-8461

REMOVAL OF HAZARDOUS AIR IMPURITIES IN THE FRAMEWORK OF IMPLEMENTING CLEANER PRODUCTION SOLUTIONS AT THE FARMUTIL COMPANY

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Keywords: air impurities, meat and bone meal, cleaner production.

USUWANIE SZKODLIWYCH ZANIECZYSZCZEŃ POWIETRZA W RAMACH WDRAŻANIA ROZWIĄZAŃ CZYSTSZEJ PRODUKCJI W FIRMIE „FARMUTIL"

W Zakładzie Rolniczo-Przemysłowym „FARMUTIL HS" w Śmiłowie, realizującym w praktyce program „czystszej produkcji", likwidacja odorów powstających podczas wytwarzania mączki mięsno-kostnej jest niezwykle ważna. Na emitorach instalacji do termicznego unieszkodliwiania odorów z produkcji mączki mięsno-kostnej wykonywano pomiary stężeń i emisji takich związków jak: pył ogółem, substancje organiczne w postaci gazów i par wyrażone jako całkowity węgiel organiczny, chlorowodór, fluorowodór, dwutlenki siarki i azotu, tlenek węgla, metale ciężkie oraz polichlorowane dibenzodioksyny i dibenzofurany. Wyniki przeprowadzonych pomiarów i analiz składu spalin emitowanych do atmosfery wykazały, że stężenie szkodliwych związków chemicznych było niskie, poniżej wartości dopuszczalnych określonych w normach.

Summary

In Agricultural and Industrial Works FARMUTIL HS at Śmiłów were „cleaner production" program has been put in practice, elimination of odors occurring during production of the meat and bone meal is of vital importance. Concentrations and emissions of total dust, organic substances in form of gas and vapors (as total organic carbon), hydrogen chloride, fluorine chloride, sulphur and nitrogen dioxides, carbon monoxide, heavy metals, polychlorinated dibenzodioxins and dibenzofurans were measured at emitters of the plant for thermal disposal of odors from the production of the meat and bone meal. The results of measurements and analyses of the composition of the flue gas emitted to the atmosphere revealed that the concentration of harmful chemical compounds was low, lower than the permissible values defined in the standards.

INTRODUCTION

For many years, the production processes were run without showing a concern about the environment. Frequently, vast amounts of wastes were generated [22]. The growing destruction of the natural environment and the depletion of natural resources resulted in the development of waste disposal technologies and a stepwise elimination of wastes from the production processes. This has led to another stage of environmental protection in industrial activity with greatest importance attached to cleaner productions methods [9, 11]. "Cleaner production" means a continued application of an integrated strategy to prevent environmental pollution with regard to production processes, products and services [2, 3]. The cleaner production concept focuses on such production management that prevents and abates the impact of the system of products on the environment. It involves mitigation of the harmful impact on the environment at every stage of the product lifecycle – starting from raw materials extraction to the ultimate end-of-life disposal [17]. The cleaner production objectives are reached due to not only changes or improvements in technologies but also due to the changed way of thinking about the ecological issues and their relevance to the economy.

The implementation of the improved cleaner technologies had to yield economical results [9]. Realizing that resulted in a changed attitude of the business people to the ecology. Owing to that, better and better organizational methods have been applied to prevent generation or improve management of wastes.

Cleaner production techniques include conservation of raw materials and energy resources, elimination of toxic raw materials, reduction in quantity and toxicity of all types of wastes. The most important of those techniques is environmental pollution prevention. Various options relating to the environmental pollution prevention form a hierarchy shown in Figure 1.

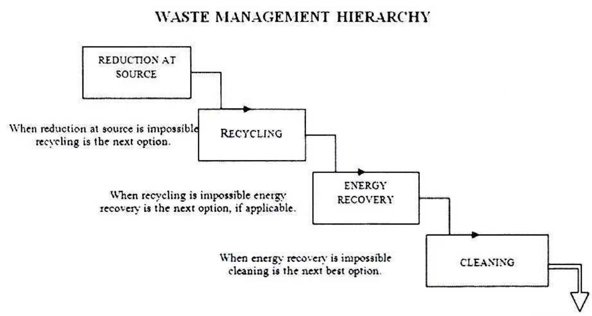


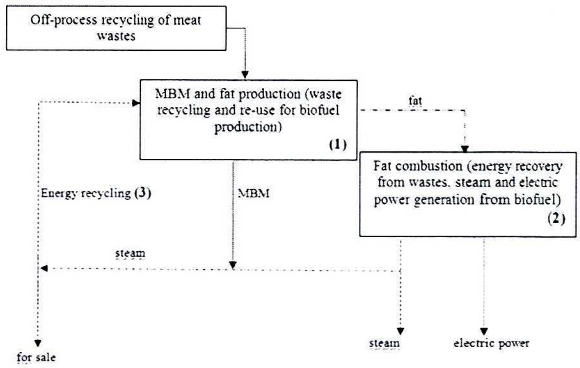
Fig. 1. Hierarchy of pollution prevention options [9]

Processing meat wastes as an exemplary cleaner production solution

Conversion of waste and side animal products into meat-bone meal (MBM) is and may continue to be the principal method of their disposal. This is due to, among other things, the dispersion of raw material producers and the nature of the meat production (in not only Poland but also in whole Europe). The MBM production and use must, however, become a cleaner technology. It is also important that processing of waste animal products is accompanied by generation of a lot of biofuel i.e. the animal fat directly used in the combustion processes for energetic purposes [8]. The meat and bone meal can be considered to be a biofuel too.

The strategic activity program at Agricultural and Industrial Works FARMUTIL HS at Śmiłów was based on the new approach to the ecological issues and their relevance to the economy. State-of-the-art technical solutions, a consistent technological system allowing for maximum recovery of energy and raw materials from the processed side animal products, many-sided utilization of biofuels recovered from that raw material, elimination of emissions are the examples of the implemented cleaner production solutions. The FARMUTIL HS works has the virtue of being a diversified production complex capable of utilizing the large energy amounts generated in the process of raw material disposal.

As concerns strategy, the elimination of odor emission is of utmost importance for the company image. Application of the thermal odor removal method in MBM production from the 1st category raw material resulted in a considerable improvement of the situation. The problem should finally be solved by the intended implementation of the thermal removal method of odors in MBM production from the 2nd and 3rd category raw materials, combined with process modernization and other detailed activities. It seems possible to create a consistent waste management system in FARMUTIL HS being an example of a production complex which uses cleaner technologies. Figure 2 is a diagram showing interconnections of energy and material flows in the existing production lines which are illustrative of the cleaner production system elements being already used.



Cleaner production options:
1 - off-process recycling of meat wastes; processing and re-use of wastes, biofuel (fat) recovery from meat wastes;
2 - energy recovery from fat (biofuel);
3 - in-process recovery of thermal energy.

Fig. 2. Diagram showing interconnections of material and energy streams in the existing production lines

Possibilities of odor removal from the meat and bone meal production process

The occurrence of odors in the area of an industrial plant and in the surroundings is one of the basic determinants of the impact of a production activity on the environment quality. That factor determines also the labor comfort and the conditions in the neighborhood of the plant. The sensory analysis examines odor persistence and determines odor intensities in a way allowing one to obtain repeatable results [7].

Smells are recognized by the human organism thanks to the olfactory cells. The information about odorants is transmitted then to the brain, more specifically, to the smell analyzer [7]. The basic term being used in the sensory analysis is the detection odor threshold. It is the concentration at which the odor can be detected by 50% of a group representative of the population. In the case of air pollution assessment, the odorant quantity which has to be added to 1 cubic meter of the air to reach the detection threshold is called an odor unit. In European Standards, the odor unit is defined basing on the reference compound i.e. n-butanol [10]. The odor intensity depends only on the number of odorant particles contacting the receptors. The odorant, as a stimulus, causes transmission of nervous impulses, the higher frequency of which is equivalent to the increase of the odor intensity [7]. The dependence of the odor intensity on the odorant concentration is described by means of psychophysical laws.

In the natural environment, there are many microbiological processes producing odors. The industry also discharges chemical compounds with an unpleasant and persistent odor to the atmosphere. There are many thousands of chemical compounds which cause unpleasant odors and differ widely in composition. The odor of gases emitted from industrial plants, waste disposal sites, municipal sewage treatment plants or animal farms is the effect of many composite mixtures of those compounds acting on the olfactory epithelium [7]. The products with the most repulsive odor which get into the air include: sulphur hydrogen, ammonia, sulphur and nitrogen oxides, thioles, sulphides, amines, aldehydes, ketones and fatty acids [7, 21].

It is possible to cope with the odors by reducing their emission, which is much easier in the case of industrial plants emitting a stream that can be captured than in the case of dispersed emission, e.g. from a waste disposal site. This can be attained, first of all, by selection of a suitable technology, modification to the applied technology, and adherence to technical and sanitary rules. A supplementary (but sometimes the only) solution is deodorization of the effluent. It can consist in removal of odorants, conversion of odorants into odorless or high-detection-odor-threshold compounds, or addition of other compounds to the effluent stream to change the nature and intensity of the odor. Quite often biological methods are employed to control odor emissions. They do not involve high investment cost; the biological material, however, is susceptible to pollutants and the biofilters take a large area. In the food industry, absorption methods combined with chemical reaction are used. The disadvantage of those methods is the origination of arduous sewage and the environmental contamination risk. Other common methods are: absorption in water, adsorption, ozonization, sorption combined with oxidation, and masking [6, 7, 20]. However, the most efficient, although investment cost intensive, are the methods of thermal oxidation of the organic compounds creating odor mixtures. The advantage of those methods is the waste-free oxidation process and the simple design of the plant [7]. At first, they were used in large municipal waste incineration plants.

A model example of a solution to the odor problem is the Spittelau plant for municipal waste incineration located in the very centre of Vienna, where 300 000 Mg of wastes are burnt per year. The municipal wastes are delivered to the incineration plant by the refuse vehicles and transferred to a concrete bunker having a capacity of 7000 Mg. There is no unpleasant odor perceptible even in the immediate vicinity of the bunker. This is due to the application of a slight vacuum (ca. 5 kPa) in the tight waste store. Air exhausted from the bunker is sent to incineration [10]. Similar solutions preventing odor emission are applied in several hundreds of large waste incineration plants all over the world.

On the premises of FARMUTIL HS at Śmiłów there are two units for utilization and disposal of hazardous animal wastes. These are Special- and High-Risk Waste Rendering Plant EKOUTIL and Rendering Plant PILUTIL. Both plants are equipped with odor removal systems.

The EKOUTIL rendering plant processing the 1st category meat wastes, which can be numbered among the most advanced plants in EU because of the technology and equipment applied, was commissioned in May, 2005.

The OXIDOR system is used there to thermally oxidize organic pollutants being the cause of unpleasant odors. Vapors from the technological line are treated. They are supplied to the thermal oxidizer's chamber through cyclones and a system of piping (Fig. 3). Also air from the raw material acceptance rooms and the production rooms is delivered there. The aforementioned rooms are enclosed and airtight, and operate under slight vacuum. The thermal oxidizer is made up of the following cooperating equipment (Fig. 4):

- rotary cup burners, fired with animal fat or natural gas;
- an oxidizing chamber provided with a refractory lining;
- a heat exchanger including chamber's piping;
- a steam boiler for the OXIDOR system;
- an exhaust fan forcing the flue gas to the stack;
- pipelines to deliver vapor from the MBM production unit and air from the production rooms.

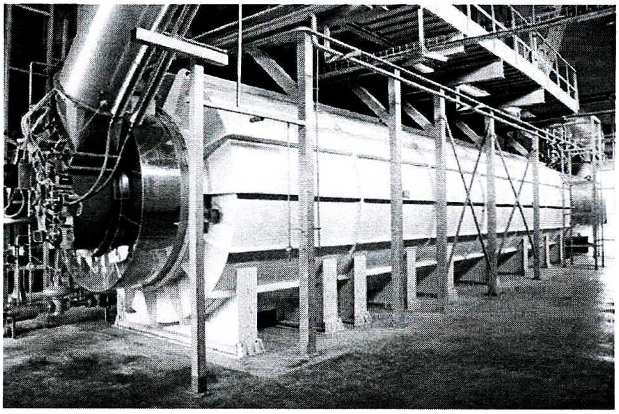


Fig. 3. Thermal oxidizer manufactured by the Spanish company Tremessa Rendering and operated at EKOUTIL

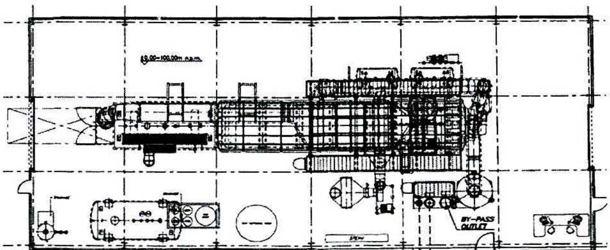


Fig. 4. Process diagram of the thermal oxidizer

In the oxidation chamber, the organic pollutants contained in the vapor and in the air and being the source of the unpleasant odor become completely oxidized and destroyed at a temperature of 950°C and the residence time of ca. 2.02 sec. The combustion products are: water vapor, carbon dioxide, traces of sulphur dioxide and nitrogen oxides. The system enables thermal disposal of more than 16 Mg/h of the process unit vapors and 25 Mg/h of the process room air. The plant is quite complicated with regard to technology and investment-cost intensive. The basic fuel is the animal fat produced in the process of meat waste rendering.

METHODOLOGY

To assess the efficiency of the EKOUTIL's odor removal system the subjective sensory analysis was used at first. The odor level assessment was made in August, 2006. A five-person panel was arranged in five locations at a distance of 30 m from the EKOULTIL's production building. After writing down the detection odor level, the panel members changed their positions in succession. All 25 assessments said the odor was imperceptible.

Other measurements, in this case of the composition of the effluent from the OXIDOR system, were carried out in April, 2006 (by the Madex company) and in July, 2006 (by the EmiPro company in cooperation with Laboratory for Trace Organic Analysis of the Cracow University of Technology and the Health Institute Laboratory, Czech Republic). The analytical results were compared with the permissible Polish [18] and EU [5] standards. To determine OXIDOR system effluent components the latest analytical methods were used. The analytical laboratories were duly accredited.

At the emitters of the EKOUTIL and PILUTIL facilities the concentrations and emissions of the following compounds were measured: total dust, organic substances in gas and vapor form (as total organic carbon), hydrogen chloride, hydrogen fluorine, sulphur and nitrogen dioxides, carbon monoxide, 12 toxic metals as well as polychlorinated dibenzodioxins (PCDD) and dibenzofurans (PCDF).

Dry gas specific density under standard conditions, the static pressure in the duct, gas temperature and moisture content were determined to define gas conditions in the duct. Those parameters were measured according to the Polish Standard [16]. The gas volume stream was measured by means of the EMIOTEST device. Gas velocity in the duct was determined basing on differential pressure measurement by means of a type S impact pressure tube. The gas volume stream is the product of the measured gas velocity and the area of the gauging section.

The concentration of dust was determined by the gravimetric method according to the standards [13, 16]. All gaseous samples were taken in duplicate by passing them through glass-fiber filters placed in a dust separator. The isokinetic flow of the gas stream taken was controlled by means of a device, of e.g. EMIOTEST 2594 type, having a heated filtration chamber. The samples were isokinetically taken from representative points of the emitter's gauging section.

In order to determine mass contents of NO_x, CO, CO_2, O_2, and SO_2 in gases leaving the thermal oxidizer, the measurements were carried out by means of a portable flue gas analyzer, LANCOM Series II. The analyzer is provided with electrochemical sensors and allows for concentrations of 3 to 9 gases to be measured. Moreover, it can measure CO_2

and the pressure. Also a microprocessor-based PHOTON analyzer was used that was equipped with an IR radiation absorption meter.

In order to determine concentrations of metals, the flue gas was passed through borosilicate glass-fiber filters placed in a dust separator with a heated filtration chamber. Afterwards it was cooled down to separate condensate. The aspiration was conducted with the isokinetic flow of the gas stream taken being controlled by means of an EMIOTEST type device. Gas samples were collected following the standards [13, 16] to ensure taking a sample representative of the stream being tested. In the sample of dust captured in the filters and in the condensate the following were determined: antimony, arsenic, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, thallium, tin, and vanadium. The chemical analysis was made using the inductively coupled plasma mass spectrometry (ICP-MS) method.

Flue gas samples to determine hydrogen chloride HCl and hydrogen fluoride HF concentrations were taken by passing the gas through sorptive solutions at a constant aspiration rate of 50–60 dm^3/h of flue gas (on dry flue gas basis under present conditions). An automatic ASP II suction apparatus was used. Also water condensate separated from the gas stream was analyzed. Sampling was done according to the standard [14] for both hydrogen chloride and hydrogen fluoride. The samples were analyzed by liquid ion exchange chromatography.

Moreover, during normal operation of the thermal oxidizer gas samples were taken to determine the content of volatile organic compounds emitted to the atmosphere. The flue gas samples were drawn in through a sorptive bed of activated carbon by means of an automatic ASP II suction apparatus at a constant volumetric rate of 20 dm^3/h. Both the volume of the samples collected and the aspiration rate were controlled. The adsorbed organic compounds were extracted with carbon disulphide CS_2. The content of organic compounds was determined by means of the capillary gas chromatography using a chromatograph equipped with a flame-ionization detector (FID).

Gas samples to determine polychlorinated dibenzodioxins and dibenzofurans were taken according to the standard [15]. Prior to sampling a mixture of ^{13}C-labelled standards of polychlorinated dibenzodioxins and dibenzofurans was spread on polyurethane foam (PUF) to determine possible losses of analytes over the long-lasting sampling process. The sample taken was passed through a borosilicate-glass fiber filter (the dust fraction) arranged in a dust separator of PTFE. After separation of the solid fraction on the solid sorbent the gas fraction was isokinetically passed through the polyurethane foam by means of EMIOTEST type devices with a heated filtration chamber.

Furthermore, water condensate was sampled which had been created due to flue gas stream cooling down. Sampling of gas was done following the standards [13, 15, 16] to ensure taking a sample representative of the stream being tested. The samples taken were analyzed according to the standard [15], parts II and III. The analytes adsorbed to the filters and to the polyurethane foam were extracted in a Soxhlet apparatus and the resulting extract was cleaned be means of multi-stage liquid chromatography techniques. After cleaning, the PCDD/Fs content in the extract was determined by means of gas chromatography coupled with mass spectrometry (GC/MS).

The toxicity level of the analyzed sample was expressed in terms of TEQ (toxic equivalents) calculated basing on the analytical results of mass contents of all PCDDs and PCDFs congeners having chlorine atoms in the 2, 3, 7, and 8 positions. The TEQ numerical value is the total of partial values derived by multiplication of the analytical result of a single congener's concentration by the corresponding toxic equivalent factor (TEF). The 2,3,7,8-PCDDS and PCDFS congeners and their corresponding toxic equivalent factors according to EN-1948 and the Directive 2000/76/EC are shown in Table 1. That value allows one to determine the potential toxicity of the preparation analyzed with regard to dioxins. According to all legal regulations, both being in force and under preparation, relating to the contents of dioxins, the mass of them is expressed as a total by mass in pg TEQ per 1 g (pg TEQ/g) or in ng TEQ per 1 kg (1 ng TEQ/kg) of the substance analyzed. For gases, it is expressed as a total by volume per 1 m^3, i.e. in ng TEQ/m^3. The TEQ by mass is calculated according to equation:

$$TEQ = \sum_{i=17}^{i=1} (m_i \cdot TEF_i)$$

where:

TEQ– toxicity level of the analyzed sample, in pg/g or ng/kg;

m_i – mass of the i-th congener of PCDD, PCDF, in pg or ng;

TEF_i– equivalent toxic factor of 2,3,7,8-TCDD for the i-th congener.

Table 1. List of 2,3,7,8-PCDDs and PCDFs congeners and the corresponding toxicity equivalents factors (TEF) according to EN-1948 and the Directive 2000/76/EC

PCDDs congener	TEF	PCDFs congener	TEF
2,3,7,8-TCDD	1	2,3,7,8-TCDF	0.1
1,2,3,7,8-P_5CDD	0.5	2,3,4,7,8-P_5CDF	0.5
1,2,3,4,7,8-H_6CDD	0.1	1,2,3,7,8-P_5CDF	0.05
1,2,3,6,7,8-H_6CDD	0.1	1,2,3,4,7,8-H_6CDF	0.1
1,2,3,7,8,9-H_6CDD	0.1	1,2,3,6,7,8-H_6CDF	0.1
1,2,3,4,6,7,8-H_7CDD	0.01	1,2,3,7,8,9-H_6CDF	0.1
OCDD	0.001	2,3,4,6,7,8-H_6CDF	0.1
		1,2,3,4,6,7,8-H_7CDF	0.01
		1,2,3,4,7,8,9-H_7CDF	0.01
		OCDF	0.001

RESULTS AND DISCUSSION

Results from research made on the EKOUTIL plant's emitter

At EKOUTIL at Śmiłów, physicochemical measurements were carried out of the composition of the flue gas emitted to the atmosphere and samples were taken – including those to determine the contents of polychlorinated dibenzodioxins and dibenzofurans (PCDDs/ PCDFs) – during normal operation of the plant, without any process upsets and at process conditions typical for its operation. The mean temperature in the thermal oxidizer's chamber was at the level of ca. 850°C, while the fat temperature upstream of the burner was 80–90°C. The purpose of the research was to determine the concentration of harmful substances emitted to the atmosphere in flue gas from the hazardous waste disposal facilities. The research was done following the requirements of the standard [19] prescribing e.g. an obligatory measurement of dioxins concentration. Gas samples were collected from measurement points installed downstream of the exhaust fan in a vertical, insulated, circular duct of steel having the inside diameter of 1.2 m. The measurement points were arranged according to the valid standard on the measurements of flue gas flows [16].

The conditions prevailing when making measurements at the EKOUTIL's emitter are summarized in Table 2. The measurement results of NO_x, CO, CO_2, O_2, SO_2, HCl, and HF contents are shown in Table 3. The measurement results of toxic metal concentrations are given in Table 4. The analysis included not only metals adsorbed to dust particles and collected on filters but also those contained in the condensate. The results of VOC's concentration measurements, determined as total organic carbon, are shown in Table 5. All the values given have been related to dry gas under standard conditions ($X \leq 0.003$ kg/kg, p = 1013 hPa and T = 273K).

Table 2. Gas parameters in the EKOUTIL's emitter duct

Physicochemical gas parameters	Unit	Sample 1	Sample 2
Atmospheric pressure	hPa	1006	1006
Air temperature	K	301	301
Dimensions	m	1.20	1.20
Surface area	m^2	1.131	1.131
Temperature	K	470	474
Static pressure	hPa	1.0	1.0
Dynamic pressure	Pa	10	5
Moisture content	kg/kg	0.225	0.086
Average velocity	m/s	5.3	3.9
O_2 content	% vol.	11.0	10.4
CO_2 content	% vol.	7.3	7.1
Dry gas density under standard conditions*	kg/m^3	1.321	1.319
Wet gas density under standard conditions*	kg/m^3	1.182	1.255
Wet gas density under measurement conditions	kg/m^3	0.683	0.718
Wet gas volume stream under measurement conditions	m^3/h	2.2E+04	1.6E+04
Wet gas volume stream under standard conditions*	m^3/h	1.3E+04	9.2E+03
Dry gas volume stream under standard conditions*	m^3/h	9.3E+03	8.0E+03

* standard conditions are: p = 1013 hPa and T = 273K

Table 3. Average concentrations of inorganic compounds in flue gases from EKOUTIL's thermal oxidizer

Series	O_2	CO_2	CO	NO	NO_2	NO_x	SO_2	HCl	HF
No.	% vol.	% vol.	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3
1	11.0	7.3	30	151	1.0	232	2.0	8.97	< 0.2
2	10.4	7.1	45	149	pgo	228	1.0	2.96	< 0.2

pgo – below determination limit

Table 4. Concentrations of metals in flue gases from EKOUTIL's thermal oxidizer

Element	Sample No.			
	1	2	1	2
	mg/sample	mg/sample	μg/m³	μg/m³
Cadmium	0.0038	0.011	0.53	1.40
Thallium	0.00046	0.00029	0.064	0.036
Mercury	0.00002	0.0066	0.0028	0.81
Antimony	0.0092	0.0030	1.30	0.37
Arsenic	0.0039	0.0023	0.024	0.006
Lead	0.027	0.020	0.54	0.28
Chromium	0.021	0.015	2.90	1.80
Cobalt	0.0014	0.00084	0.20	0.10
Copper	0.12	0.069	17.0	8.50
Manganese	0.28	0.17	39.0	21.0
Nickel	0.020	0.010	2.80	1.20
Vanadium	0.00056	0.00027	0.078	0.033
Tin	0.0030	0.0012	0.42	0.15

Table 5. Results of C_{org} measurements in flue gas from EKOUTIL's thermal oxidizer

Sample	Sample volume	C_{org} mass in sample	C_{org} concentration
No.	dm³	μg	mg/m³
1	8.9	7.56	0.85
2	8.6	7.38	0.86

The most hazardous group of compounds determined in the gases emitted from the hazardous waste incineration unit is polychlorinated dibenzodioxins and dibenzofurans. Those compounds show carcinogenic, mutagenic, teratogenic, and estrogenic properties. They are capable of accumulating in living organisms and, due to their lipophil nature, accumulate in fats. Because of their harmfulness very sharp rigors are imposed on the hazardous waste rendering plants permitting the maximum concentration of those compounds in the gases emitted at the level of 0.1 ng TEQ/m³. The results of determinations for dioxins and furans content are presented in Table 6.

Table 6. Measurements results of dioxins and furans concentrations in flue gas from EKOUTIL's thermal oxidizer

Congener No. i	Congener	TEF_i	Congener mass m_i	Partial TEQ $m_i \times TEF$	Congener concentration c_i
			ng/sample	ng TEQ/sample	ng TEQ/m³
1	2,3,7,8-TcCDD	1.0	0.040	0.040	0.00262
2	1,2,3,7,8-PcCDD	0.5	0.261	0.131	0.00858
3	1,2,3,4,7,8-HxCDD	0.1	0.212	0.0212	0.00139
4	1,2,3,6,7,8-HxCDD	0.1	0.345	0.0345	0.00226
5	1,2,3,7,8,9-HxCDD	0.1	0.205	0.0205	0.00134
6	1,2,3,4,6,7,8-HxCDD	0.01	0.839	0.00839	0.00055
7	OCDD	0.001	1.184	0.00118	0.00008
8	2,3,7,8-TcCDF	0.1	0.566	0.0566	0.00371
9	1,2,3,7,8-PcCDF	0.05	0.681	0.03405	0.00223
10	2,3,4,7,8-PcCDF	0.5	1.149	0.575	0.03766
11	1,2,3,4,7,8-HxCDF	0.1	1.738	0.1738	0.01138
12	1,2,3,6,7,8-HxCDF	0.1	1.363	0.1363	0.00893
13	1,2,3,7,8,9-HxCDF	0.1	2.260	0.2260	0.01480
14	2,3,4,6,7,8-HxCDF	0.1	0.001	0.0001	0.00001
15	1,2,3,4,6,7,8-HpCDF	0.01	4.465	0.0447	0.00293
16	1,2,3,4,7,8,9-HpCDF	0.01	0.389	0.00389	0.00025
17	OCDF	0.001	1.397	0.00140	0.00009
Total PCDDs/Fs				1.5086	0.0988

A hazardous waste rendering plant, such as EKOUTIL at Śmiłów, is obliged to keep low concentration of the pollutants emitted, the control of which is prescribed by the regulations in force. Table 7 shows a list of the pollutants controlled, their concentrations in the gases emitted, and the permissible levels according to [18].

Table. 7. Measurements results of pollutants concentration in flue gas from EKOUTIL's thermal oxidizer in comparison with the standard [18]

Analyte	Values measured	Permissible concentration of pollutants
	mg/Nm³ for 11% O_2	mg/Nm³ for 11% O_2
C_{org}	0.83	10
HCl	5.9	10
HF	< 0.2	1.0
NO_x	223	200
SO_2	3	50
CO	36	50
O_2 in % vol.	10.7	results for 11%
Cadmium	0.00092	
Thallium	0.000049	
Cadmium + Thallium	0.0010	0.05
Mercury	0.00038	0.05
Total metals	0.04015	0.5
Antimony	0.00083	
Arsenic	0.00041	
Lead	0.0031	
Chromium	0.0023	
Cobalt	0.00015	
Copper	0.0013	
Manganese	0.030	
Nickel	0.0020	
Vanadium	0.000055	
Dioxins	0.096 ng TEQ/Nm³ per 11% O_2	less than 0.1 ng TEQ/Nm³

Results from research made on the PILUTIL plant's emitter

The analyses of gases emitted from Rendering Plant PILUTIL at Śmiłów were made by Firma Madex from Gdańsk. The composition of the flue gas was examined, including polychlorinated dibenzodioxins and dibenzofurans (PCDDs/PCDFs) – so called dioxins – emitted to the atmosphere. The samples were collected during normal operation of the plant, without any process upsets, at process conditions typical for that plant. The research was made according to the standards [19] and the results were compared with the permissible concentration levels [18], which are shown in Table 8.

Table 8. Measurements results of pollutants concentration emitted at PILUTIL in comparison with the standard [18]

Analyte	Values measured	Permissible concentration of pollutants
	mg/Nm³ for 11% O_2	mg/Nm³ for 11% O_2
C_{org}	4.0	10
HCl	5.0	10
HF	0.4	1.0
NO_2	360	non-standardized
SO_2	52	50
CO	27	50
O_2 in % vol.	11.4	results for 11%
Dust	100	10
Cadmium + Thallium	0.0103	0.05
Mercury	0.0003	0.05
Total metals (Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V)	0.0642	0.5
Dioxins	0.018 ng TEQ/Nm³ per 11% O_2	less than 0.1 ng TEQ/Nm³

CONCLUSIONS

According to the valid regulations on the requirements concerning measurements of emissions [19] and the standards of emissions from plants [18] and the decision of the province governor [4], a plant owner is obliged to operate it so that it should meet Polish and European pollution emission standards.

Hazardous waste (including waste animal tissues) rendering plants are subject to particular control. They are required to measure many parameters and concentrations of chemical compounds and to adhere to very strict permissible emission rigors.

The measurements and analyses of the composition of flue gases emitted to the atmosphere from the plant for thermal utilization of fats and hazardous air impurities from the production of meat and bone meal in the area of EKOUTIL at Śmiłów proved that the concentration of harmful chemicals in the gases emitted was low, lower than the permissible levels defined in the standards [19].

Similarly, for PILUTIL, the research demonstrated that the concentration of harmful chemicals in the gases emitted was low, lower than the permissible levels defined in the standards [19].

The problem of the hazardous air impurities unpleasant odors connected with plant operation should be definitely solved soon thanks to the implementation of the OXIDOR system in other production plants of FARMUTIL HS and the improvement of the existing system.

Solutions such as the OXIDOR system are technically complicated and involve high investment cost. The example of successful removal of hazardous air and vapor impurities at EKOUTIL evidences, however, that such systems are worth of investing in.

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Received: May 15, 2007; accepted: October 2, 2007.