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REFORMING THE HAZARDOUS WASTE DISPOSAL SECTOR IN UKRAINE

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Bringing the Ukrainian regulatory system in the field of hazardous waste in line with the norms and rules in force in the European Union requires significant changes in both legislative and regulatory and methodological support of permitting procedures for thermal disposal of hazardous waste. The first steps on this path have already been taken. The latest drafts of the Laws of Ukraine "On Prevention, Reduction and Control of Pollution Arising from Industrial Activities" and "On Waste" reflect the mechanisms for regulating the thermal disposal of waste set out in Directive 2010/75 / EU on industrial emissions. Further steps should be aimed at regulatory and methodological support for the implementation of these mechanisms in Ukraine. This article is devoted to the analysis of the necessary changes in the normative and methodological support of the procedures for issuing integrated permits for hazardous waste incineration. In particular, new requirements for the environmental efficiency of the combustion plant, requirements for monitoring the basic parameters of the technological process, emissions and discharges.

Further limitation of emissions from waste incineration leads to a significant increase in the cost of equipment in gas purification systems. But the achievement of emission standards can be achieved not only by improving the flue gas cleaning system, but also by preventing the formation of secondary toxic compounds in the destruction of hazardous waste. This approach can provide the desired result with much lower capital and operating costs. In particular, the destruction of chlorine-containing toxic components of waste in the melt of alkali metal compounds prevents the formation of secondary toxic compounds, and the additional module in which the destruction takes place is compatible with many conventional hazardous waste incineration systems. *Key words:* hazardous waste, environmental efficiency, incineration plants.

Реформування сфери видалення небезпечних відходів в Україні. Бондар О.І., Риженко Н.О., Четвериков В.В.

Приведення української регуляторної системи в галузі поводження з небезпечними відходами у відповідність до норм та правил, що діють у Європейському Союзі, потребує істотних змін як у законодавчому, так і нормативно-методичному забезпеченні процедур надання дозволів на діяльність із термічного знешкодження небезпечних відходів. Перші кроки на цьому шляху вже зроблені. В проектах Законів України «Про запобігання, зменшення та контроль забруднення, що виникає в результаті промислової діяльності» та «Про відходи» відображені механізми регулювання сфери термічного знешкодження відходів, що викладені в Директиві 2010/75/ЄС про промислові викиди. Подальші кроки мають бути націлені на нормативно – методичне забезпечення реалізації в Україні таких механізмів. Саме аналізу необхідних змін у нормативно-методичному забезпечені процедур надання інтегрованих дозволів під час спалювання небезпечних відходів присвячена ця праця. Зокрема, окреслені нові вимоги щодо екологічної ефективності спалювальної установки, до моніторингу базових параметрів технологічного процесу, викидів та скидів.

Подальше обмеження норм викидів під час спалювання відходів призводить до значного подорожчання обладнання в системах очищення газів. Проте досягти зменшення викидів можна не лише завдяки вдосконаленню системи очищення димових газів, але й шляхом запобігання утворенню вторинних токсичних сполук при деструкції небезпечних відходів. Такий підхід може дозволити одержати необхідний результат за значно менших капітальних та експлуатаційних затратах. Зокрема, деструкція хлоровміщуючих токсичних компонентів відходів у розплаві сполук лужних металів запобігає утворенню вторинних токсичних сполук, а додатковий модуль, в якому здійснюється деструкція, є сумісним з багатьма класичними системами спалювання небезпечних відходів. *Ключові слова:* небезпечні відходи, екологічна ефективність, спалювальні установки.

Introduction. Processes of hazardous waste thermal disposal are accompanied by formation of a wide range of new products, which can have even more hazardous properties than waste original components in case of wrong organization of the technological process. Mechanisms of hazardous products formation during thermal disposal of waste hazardous components have been subject of research for many years. Research methods are constantly being improved. Recently, methods of mathematical modeling are increasingly used in research. This allowed to determine the most effective means of preventing formation and removal of toxic products in thermal disposal of hazardous waste and to summarize the practical experience of such technological processes. In world practice, generalized experience is embodied in reference documents on best available techniques (BAT). Compliance of technologies for hazardous waste thermal disposal with basic indicators of environmental, energy and economic efficiency has become a basic criterion for the issuance of permits for activities that affect the environment in many countries around the world. In Ukraine, the Verkhovna Rada is considering a draft Law of Ukraine "On Prevention, Reduction and Control of Pollution Arising from Industrial Activities", which should bring the regulation of industrial impacts on the environment in line with international practices. Enactment of this law should radically reform the regulatory system and technological base of hazardous waste thermal disposal.

Technical regulation of thermal disposal of hazardous waste. The Association Agreement between Ukraine and the European Union provides for approximation of national legislation in the field of environmental protection to EU legislation. One of the main tasks of reforming the sector is to enshrine in national legislation the provisions of Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control). Implementation of Directive 2010/75/EU provisions should radically change permitting system for activities that impact environment, and in particular licensing of hazardous waste disposal activities [1]. In addition to organizational aspects of application consideration for the implementation of activities in the Ukrainian legislation should be transferred the qualitative and quantitative requirements for thermal disposal processes, formed on the basis of best European techniques and practices.

Integrated permit for waste incineration plants in accordance with Directive 2010/75/EC must contain the following information:

– a list of all types of waste which may be treated is compiled in accordance with the European Waste List established by Decision 2000/532/EC;

– the total waste from incinerating or co-incinerating capacity of the plant:

– the limit values for emissions into air and water;

– requirements for pH, temperature and volume of discharges;

– procedures and frequency of sampling and measurement;

– the maximum permissible period of any technically unavoidable stoppages, disturbances, or failures of the purification devices or the measurement devices, during which the emissions into the air and the discharges of waste water may exceed the prescribed emission limit values.

When incinerating hazardous waste, in addition to the above information, permit must limit minimum and maximum volumes of hazardous waste, their lower and maximum calorific value and maximum content of polychlorinated biphenyls, pentachlorophenol, chlorine, fluorine, sulfur, heavy metals and other pollutants.

To support procedures of permits examination, the European Commission Decision of 12 November 2019 adopted a list of recommended procedures and operations arising from BAT analysis and generalization for waste incineration. BAT are given in the form of recommended procedures and operations description. Specific data only apply to BAT-AELs (associated emission levels) and the frequency of their measurement. In total, the document contains 37 BAT, which belong to the following sections:

– Methods of environmental management system improving (EMS)

– Methods to increase incinerator environmental efficiency

– Methods to prevent or reduce air emissions

– Methods to prevent or reduce discharges into the water

– Methods to improve energy efficiency

– Methods to increase resource efficiency

– Monitoring of technological parameters, emissions and discharges.

Methods of increasing the environmental efficiency of the combustion plant. Improving the environmental efficiency of incinerators can be done in two ways:

– improving of waste toxic components destruction and neutralization;

– improvement of gas cleaning systems

The main requirements for waste incineration processes are formulated directly in Directive 2010/75 / EU:

1. The combustion regime must ensure that content of organic carbon in slag and ash residues is less than 3%.

2. When incinerating hazardous waste with a chlorine content exceeding 1%, gases temperature near the combustion chamber wall after the last oxidant introduction (preheating zone) was maintained at least 1100 ° C for two seconds.

3. Each incinerator combustion chamber must be equipped with at least one auxiliary burner which switches on automatically when combustion products temperature in the preheating zone falls below 1100 ° C. Burners are also used during start-up and shut-down operations.

4. Incinerators must have an automatic waste blocking system when starting the installation until temperature specified in paragraph 2 is reached or as a result of deviation from the technological mode is not maintained at required level, as well as when due to disturbances in gas purification system the maximum content of any pollutant in flue gases is exceeded.

These requirements are reflected in the draft new version of the Law of Ukraine "On Waste" and may soon become mandatory [2].

Decision of the European Commission to implement Directive 2010/75/EU does not contain specific recommendations on the BAT for chlorine-containing hazardous waste destruction and neutralization. Many computational, analytical and experimental studies have been devoted to the optimization of these processes, the results of which may be difficult to draw a few concrete conclusions, but they can provide sufficient information on the procedure for examining documentation for integrated permitting.

Enactment of the Law of Ukraine "On Prevention, Reduction and Control of Pollution Arising as a Result of Industrial Activity" creates regulatory and legal preconditions for improving gases cleaning systems of incinerators.

In Ukraine, emissions of pollutants from stationary sources are regulated by general standards of maximum permissible emissions of pollutants from stationary sources. In addition, for certain types of thermal equipment, current and future technological standards are set, which relate to pollutants inherent in the technologies implemented on this equipment. To date, several technological standards have been developed for emission sources in metallurgy and energy. There are no such standards for the waste incineration yet. With introduction of integrated permitting systems in Ukraine, regulatory framework should reflect levels of emissions and discharges specified in the Decision of the European Commission of 12 November 2019 on BAT-AELs. The list of pollutants emission limit values, means of their removal, the frequency of their control, according to BAT-AELs, are shown in table 1.

Table 1

Emission levels for incinerators according to BAT-AELs

Contaminant	BAT-AEL mg/Nm^3		Averaging period	Measures and means of removal
Dust, metals and metalloids				
Dust	< 2–5[1]		daily average	Bag filters, electrostatic precipitators, dry sorbent injection, wet scrubber, fluidized bed or fixed bed adsorption and combinations thereof
Cd+Tl	0,005–0,02		average over the sampling period	
Sb+As+Pb+Cr+Co+ +Cu+Mn+Ni+V	0,01–0,3		average over the sampling period	
Dust from the closed processing of slag and bottom ash	2–5		average over the sampling period	
HCl, HF & SO_2				
	New installation	Existing installation		Wet scrubber, semi-dry scrubber, dry sorbent introduction, direct desulfurization (for fluidized bed)
HCl	< 2–6[2]	< 2–8	daily average	
HF	< 1	< 1	daily average or average over the sampling period	
SO_2	5–30	5–40	daily average	
NO_X & CO				
NO_X	50–120[3]	50–150[4]	daily average	Flue gas recirculation, selective non-catalytic reduction (SNCR), selective catalytic reduction (SCR), bag filters with catalyst, wet scrubber
CO	10–50	10–50		
Total volatile organic carbon, PCDD/F and dioxin-like PCBs				
Total volatile organic carbon, mg/Nm^3	< 3–10	< 3–10	daily average	Rapid cooling of the flue gas from a temperature above 400 °C to below 250 °C to prevent the synthesis of PCDD / F, introduction of dry sorbent, adsorption in fluidized or fixed bed, selective catalytic reduction, bag filters with catalyst, carbon sorbent in wet scrubber
PCDD/F, ng I-TEQ/nm^3	<0,01–0,04	< 0,01–0,06	average over the sampling period	
	<0,01–0,06	<0,01–0,08	long-term sampling period	
PCDD/F + dioxin-like PCBs, of WHO-TEQ/Nm^3	<0,01–0,06	<0,01–0,08	average over the sampling period	
	<0,01–0,08	<0,01–0,1	*long-term sampling period*	
Mercury				
Hg, mkg/Nm^3	< 5–20	*< 5–20*	daily average or average over *sampling period*	*Wet scrubber (low pH), introduction of dry sorbent, introduction of special highly activated carbon, adsorption in fluidized or fixed bed*
	1–10	1–10	*long-term sampling period*	

[1] For existing plants dedicated to the incineration of hazardous waste and for which a bag filter is not applicable, the higher end of the BAT-AEL range is 7 mg/Nm^3.

[2] The lower end of the BAT-AEL range can be achieved when using a wet scrubber; the higher end of the range may be associated with the use of dry sorbent injection.

[3] The lower end of the BAT-AEL range can be achieved when using SCR.

[4] For existing plants fitted with SNCR without wet abatement techniques, the higher end of the BAT-AEL range is 15 mg/Nm^3.

Monitoring of basic parameters of technological process, emissions and discharges. An important factor in preventing pollution during thermal disposal of hazardous waste is to obtain prompt and reliable information about technological process. Therefore, in pursuance of Directive 2010/75/EU, the European Commission has established a list of basic process parameters and a list of pollutants to be controlled during waste heat treatment.

Basic technological process parameters that affect emissions and discharges from the incinerator and should be controlled in accordance with the BAT are given in Table 2.

Processes in which air emissions are controlled, the frequency of measurements are shown in table 3.

When burning hazardous waste containing persistent organic pollutants (POPs) it is necessary to determine POPs content in final products (slag and ash, flue gases, wastewater) both during incinerator commissioning and after each change that may significantly impact on the POPs content in final products.

Application of measures and means of flue gas cleaning from pollutants recommended by the BAT requires a significant increase in capital and operating costs for gas cleaning systems. Therefore, in order to reduce load on the gas cleaning system and, accordingly, to reduce

Table 2

Basic parameters of the technological process

Measurement object	Parameters	Measurement frequency
Flue gases from the incineration of waste	Flow, oxygen content, temperature, pressure, water vapour content	Continuous measurement
Combustion chamber	Temperature	
Wastewater from wet gas cleaning devices	Flow, pH, temperature	
Wastewater from bottom ash treatment plant	Flow, pH, conductivity	

Table 3

Processes in which air emissions are controlled and frequency of measurements

Compound / parameter	Process	Minimum measurements frequency
NO_X	Waste incineration	Continuously
NH_3	Waste incineration with SNCR and/or SCR is used	Continuously
N_2O	Incineration of waste in a fluidized bed furnace Incineration of waste when SNCR is operated with urea	Once a year
CO	Waste incineration	Continuously
SO_2	Waste incineration	Continuously
HCl	Waste incineration	Continuously
HF	Waste incineration	Continuously [1]
Dust	Battom ash treatment	Once every year
	Waste incineration	Continuously
Metals and metalloids, except mercury (As, Cd, Co, Cr, Cu, Mn, Ni, Pb, Sb, Tl, V)	Waste incineration	Once every six months
Hg	Waste incineration	Continuously
TVOC	Waste incineration	Continuously
PCDD/F	Waste incineration	Once every six months for short-term sampling
		Once a month for long-term sampling
Dioxin-like PCBs	Waste incineration	Once every six months for short-term sampling [2]
		Once a month for long-term sampling
Benz[a]pyrene	Waste incineration	Once every year

[1] The continuous measurement of HF may be replaced by periodic measurements with a minimum frequency of once every six months if the HCl emission levels are proven to be sufficiently stable. No EN standard is available for the periodic measurement of HF.

[2] The monitoring does not apply where the emissions of dioxin-like PCBs are proven to be less than 0,01 ng WHO-TEQ/Nm^3.

capital and operating costs, research is being carried out to improve waste thermal destruction technology.

A promising direction for improving of chlorine-containing hazardous waste thermal disposal technology is destruction in molten salts of alkali metals.

Preliminary studies of of POPs-containing wastes thermal disposal have shown that, after destruction in the melt, chlorine is completely bound to alkali metal chlorides, thus eliminating formation of secondary chlorine-containing toxic compounds [3]. Accordingly, resulting synthesis gas does not require purification and can be discharged as an auxiliary fuel in conventional incinerators. Destruction of highly concentrated POPs can be performed in an additional module to the incinerator. The module will create almost no additional load on the incinerator's gas purification system, and capital costs for this module will be much lower than for gas purification system creation with traditional technology of thermal disposal of highly concentrated chlorine-containing waste.

Destruction of POP-containing pesticides and PCB-containing oils in molten salts of alkali metals is carried out according to the technological scheme shown in Figure 1.

Sodium and potassium carbonates and sodium sulphate are loaded into the pyrolysis chamber 1 preheated to 950 ° C through the gateway chamber 2. There is a constant recirculation of the melt between the pyrolysis chamber and the bubbling chamber as a consequence of the airlifting effect from the operation of the submerged burner [4].

Loading of solid waste POPs begins when temperature in bubble chamber 3 reaches 950 °C. Solid wastes in paper bags are fed by a belt conveyor to the gateway loader. Through it, by alternately opening gates, bags get inside the oven. Loading of liquid and bulk materials is carried out continuously from the tank 4 and the hopper with screw dispenser 5 through the lance 6.

For their transportation air with the addition of water vapor, formed by cooling the fused melt in the tank 9 can be used. Gasification of POPs can begin in the lance 6 and continue in the melt bath.

In the melt bath at temperatures around 950°C POPs compounds participate in several subsequent reactions. Initial reaction is pyrolysis and partial oxidation with sulfate to form a coke residue, water vapor, CO, some hydrocarbons and acid gases. Acid gases are neutralized by alkali salt. Coke residue remains in sulfate melt in first zone until completely reacted with sulfate. Reaction of the coke residue with sodium sulfate to produce sodium sulfide is endothermic. Sulfide on the bath surface reacts with oxygen in the air regenerating back into sodium sulfate. Chlorine in the melt binds to sodium chloride and remains in the melt.

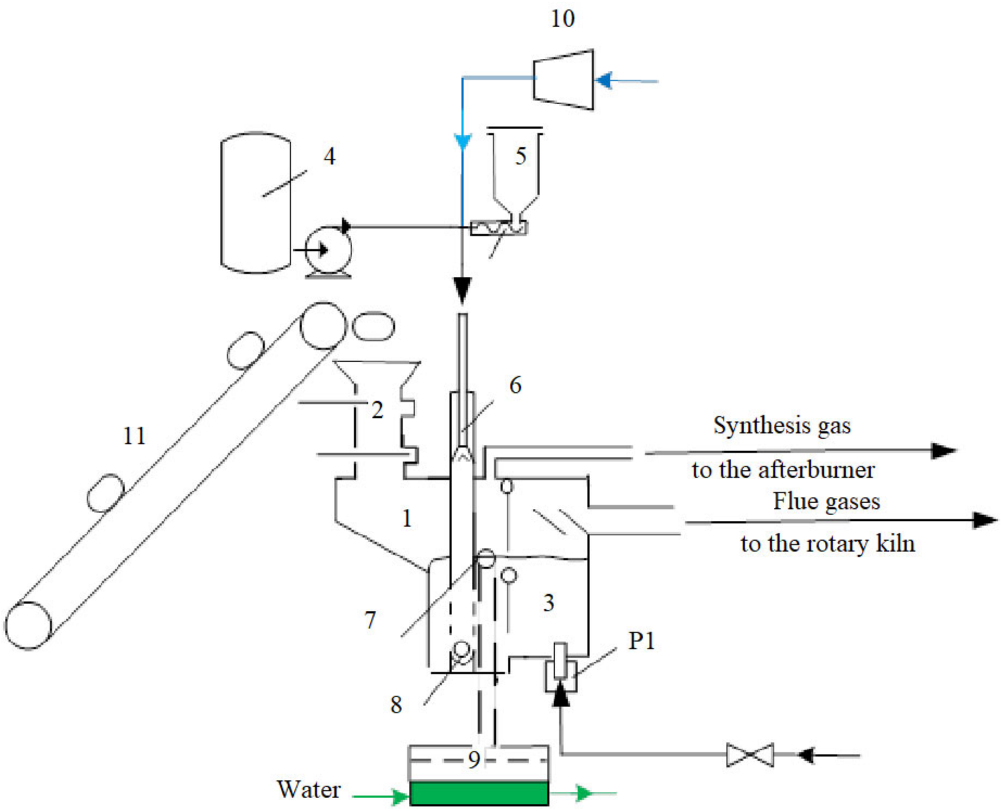

Fig. 1. Module of destruction of concentrated POPs: 1 – pyrolysis chamber; 2 – gateway chamber; 3 – bubble chamber; 4 – container for liquid waste; 5 – screw dispenser; 6 – lance; 7 – upper drain hole; 8 – lower drain hole; 9 – tank for draining the melt; 10 – compressor; 11 – conveyor; P1 – submerged burner;

Gaseous destruction products leave destruction module through the window in the pyrolysis chamber and are fed to rotary kiln afterburner. Flue gases from bubble chamber enter the rotary kiln as additional coolant.

As previous studies have shown, the destruction of PCBs in the melt of carbonates and chlorides of alkali metals can reach 99.999999% [5]. Concentration of dioxins and furans in obtained products, was at level of picograms. Thus, completion of the technological complex with an additional module for concentrated POPs destruction will effectively neutralize almost all types of chlorine-containing waste. Specific costs of disposal in such an upgraded version of technological complex will be much lower than when using one large universal rotary kiln or several specialized installations.

Conclusions

1. The harmonization of the Ukrainian legal framework for the regulation of hazardous waste management with European directives requires radical changes in procedures and criteria used for permits issuance for activities related to negative environmental impacts.
2. Expansion of pollutants list that must be controlled during hazardous waste thermal disposal and establishment of emission limit values based on the best available techniques s and practices require significant improvements in gas purification systems used in domestic incinerators.
3. Reduction of pollutant emissions can be achieved not only by improving gas cleaning systems, but also by preventing secondary toxic compounds formation from destruction products.
4. Destruction of chlorine-containing toxic components of waste in the molten salts of alkali metals compounds prevents formation of secondary toxic compounds. Inclusion of the destruction in the melts module in the technological chain can significantly reduce the load on the gas purification system.

References

1. Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control). URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32010L0075 (дата звернення 11.05.2022)
2. Закон України «Про відходи» № 187/98-ВР (05 березня 1998). *Законодавство України. Верховна Рада України*. URL: https://zakon.rada.gov.ua/laws/show/187/98-%D0%B2%D1%80#Text (дата звернення 11.05.2022)
3. Четвериков В.В. Газификация отходов в расплавах солей щелочных металлов : матеріали XX ювілейної (щорічної) міжнар. конф. «Экологическая и техногенная безопасность. Охрана водного и воздушного бассейнов. Утилизация отходов», м. Бердянськ, 1–15 черв. 2012 р. / УкрВОДГЕО. С. 421–424
4. Плавильна піч для знешкодження токсичних речовин: пат. 16042 Україна : F23G 7/100. № u 200601625; заявл. 16.02.2006; опубл.17.07.2006, Бюл. № 7. 6 с.
5. Disposal of PCB. Patent USA № 4246255. 1972.