11.3 Assessment of the Best Available Techniques (BAT)

CONTENTS

11.3 Assessment of the Best Available Techniques (BAT)

The assessment is based on:

- A literature research on international experience for plasma based waste treatment, the evaluation of IAEA recommendations and information due to the Best Available Techniques for minimization of radioactive emissions,
- An assessment of the compliance with the Best Available Techniques Reference Documents (BREF) requirements on waste incineration, especially for the off gas treatment,
- The comparison of the requirements in the new Directive 2010/75/EU on industrial emissions for the minimization of conventional air pollutants emissions,
- And finally, the assessment and comparison of the emission values for the Kozloduy PMF, the ZWILAG PMF and the CILVA incineration facility.

11.3.1 International experience for plasma based waste treatment

In publication [12] the thermal plasma technology for the treatment of wastes is reviewed in comparison with incineration technologies. The treatment of RAW is definitely outside of the scope of this review, but the conclusions can also be taken into account for RAW treatment.

This technology can be seen as a viable alternative for conventional mature thermal processes.

Advantages of this technology are:

- High throughput with compact reactor geometry (reactor= treatment chamber);
- The high heat flux densities lead to fast attainment of the operation conditions, allowing fast start and shut down times;
- For the process no heat oxidants are required to produce process heat, therefore the gas stream volume is much lower in comparison to waste incineration;
- The technology can be used for a wide range of waste, combustible and non-combustible.

Examples for this wide range of use are described in [13] plasma pyrolysis of medical waste and [14] plasma treatment of rubber waste.

Already at the end of the last century investigations about the use of plasma technology for the treatment of operational RAW in Japan were executed. Reasons for these activities were to find solutions for the main topics: volume reduction and stabilization of radionuclide, acceptable for final disposal [15]. In the Japan Atomic Research Institute an “advanced volume reduction program” for LLIW was realized [16]. As advantage of this technology was stated:

- The final product is a stable solid with fixed and very low level leachability which can be disposed in near surface repositories.

Amongst others investigations about the retention of the main nuclides ^{60}Co and ^{137}Cs in the slag resp. vitrified final product [16], [17] were executed. As influence factors

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the basicity of the slag (ratio CaO/SiO_2), the content of chlorine in the input material, area of the molten slag surface and the duration of dwell were identified. Other aspects respectively advantages of the plasma technology for treatment of RAW are stated in [18]:

- The complete removal of the organic load in the waste and thus prevention of possible generation of burnable gases (e.g. hydrogen) by radiolysis;
- In comparison to incineration plants the plasma technology leads to a marked decrease in the size of the treatment plant.

An economical and technical assessment of vitrification technologies in the frame of a feasibility study was executed for the development of the strategy for the RAW treatment from the NPP in South Korea [19]. The following technologies were assessed:

- o Cold Crucible Melter heated by induction,
- o Cold Crucible Melter heated by vertical electrodes,
- o Quantum Catalytic Extraction Process, and
- o Plasma Torch.

This study includes the technical assessment with the main parameters:

- Waste feeding (highest factor when all kinds of waste can be treated)
- Necessary replacement of materials during the melter life
- Melter life
- Throughput
- Entrainment (retention) of Cs in waste.

And the economical assessment with the main parameters:

- Capital and operation cost;
- Disposal costs based on the disposal volume, calculated with reasonable estimated volume reduction factors by considering the waste type and the treatment concept.

As result of the assessment it was stated that the Cold Crucible Melter is the best option for the treatment of combustible waste and that the Plasma Torch Melter is the best option for non-combustible RAW. Only with the Plasma Torch Melter all kinds of RAW can be treated.

A concept for treatment and storage of all kinds of RAW from all operating NPP was realized in Switzerland. The responsible ZWILAG AG operates storage and conditioning facilities, among others a plasma melting facility [20].

This facility was commissioned in 2004; main aspects for the erection of this plant were the volume reduction and the consistence of the final product, suitable for the final storage in geological formations. This plant is the first which uses the plasma technology for treatment of RAW. The experience from the concept, the design, the operation and the improvements were used by the JV for the PMF project Kozloduy.

More details about this facility, related to radiological and non radiological emissions and operational experience are given in the protocol about an information visit at the ZWILAG Plasma Melting Facility [60].

Other data concerned operational experience of the same facilities as a PMF at Kozloduy NPP are presented below in section 11.3.1.1.

11.3.1.1 Operational Experience of Equipment/Facilities Similar to Kozloduy NPP, Project: Plazma Melting Facility (PMF) at Kozloduy NPP, ID: I-200-RP-0238, Rev. 0

1. Object

The object of this report is to compile the operational experience gained in similar facilities to Kozloduy PMF in order to assure that all applicable lessons learned have been considered in the Kozloduy PMF design and all appropriate technical solutions have been included.

Regulation on *Ensuring the Safety of Nuclear Power Plants* establishes in its Art.129 that operational experience of own and other's facilities should be collected to identify the good operational practices and events, and to evaluate safety significant operational events.

Although previous regulation is applicable to Nuclear Power Plants (as clearly noted in its Art. 1) and therefore it is not focused on RAW treatment facilities, Art. 129 has been considered in order to assure that available operational experience and BAT have been included in the Kozloduy PMF Project (the Project).

2. Scope

This report includes information related to the operational experience collected during the Installation, commissioning and operation/maintenance phases of similar facilities to the Kozloduy PMF.

This report incorporates information of different RAW treatment and conditioning facilities such CILVA incinerator facility (section 5.1) or ZWILAG plasma facility (section 5.2).

Additionally, and in order to consider as much information as possible, this report also includes operational experience of equipment similar to that installed in the Kozloduy PMF but in operation in other industrial applications (including nuclear and non-nuclear applications).

Section 5 of this document lists and briefly describes all the aforementioned reference facilities. The list of defects/failures of the equipment and components of referenced facilities has been included as part of the operational experience. This list incorporates the deviations and events during the installation, commissioning and operation of the facility.

3. References

3.1. Regulation on Ensuring the Safety of Nuclear Power Plants, accepted with LMC No.172 dated 19 July 2004, promulgated in State Gazette No. 66, 30 July 2004, last amended, SG No. 5 /19.01.2010.

3.2. I-200-RP-0016 – Acceptance criteria for incoming RAW.

4. Lessons learned and operational experience of similar facilities or equipment to Kozloduy NPP PMF

The Project is led by the Joint Venture of IBERDROLA Ingeniería y Construcción S.A.U. and BELGOPROCESS N.V. These companies have demonstrated experience in the design, manufacturing and operation of RAW treatment and conditioning facilities. In addition to the JV, other sub-contractors are working for the Project under JV supervision. All these subcontracted companies have demonstrated experience in their respective scopes, particularly, the Project has the knowledgeable support of the ZWILAG responsible facility (Switzerland), being the only RAW Plasma Melting Facility in operation in the world.

The Kozloduy PMF team formed by previous noted companies assure the use and applicability of the BAT and available Lessons Learned due to the involved parties are pacesetter companies in the technology applicable to their scope of work.

Moreover, in order to assure that all applicable Lessons Learned have been incorporated in the Project, existing available operational experience has been analysed and the result have been documented in present report. Collected lessons learned and operational experience have been structured in sections according to the affected PMF sub-systems (refer to sections 4.1 to 4.6).

4.1 Lessons Learned and Operational Experience applicable to the Feeding

Design Improvements: following lessons learned gained similar facilities have been taking into account in the Kozloduy PMF design:

- Installation of infrared detectors to control the material levels in the hoppers.

- Using of belt conveyors instead roller conveyors to transfer the waste packages smoothly.

- Installation of frequency controlled drives to improve the movement of the belts.

- Installation of flow controllers to improve the movement of the pneumatic belt.

- Installation of a pushing device to avoid the ‘jumping’ or ‘bridging’ of waste over the shredder knives.

- Installation of a dual shredder to assure adequate size of the shredded pieces

- Installation of a robust hydraulic driven screw feeder to avoid blocking problems

- Installation of a blanketing system in the airlock and the shredder (with N2) as preventive action in order to avoid explosions due to the accidental feeding of flammable liquids or solvents (see section 5.2 of document I-200-RP-0016 – *Acceptance criteria for incoming RAW,* for accepted liquid criteria).

4.2 Lessons Learned and Operational Experience applicable to the Plasma Treatment

Design Improvements: following lessons learned gained in referenced facilities have been taking into account in the Kozloduy PMF design:

- Selection of a tilting furnace as PTC to improve the control of the pouring process avoiding pouring hole blocking issues.

- Removable design of the supplementary liquid feeding injection nozzle

- Feeding system concept assuring the pressure control into the system

- Drainage at the bottom of the furnace to allow the evacuation of the water during refractory drying operations

- Installation of cooling water jackets in the furnace in order to enlarge the life time of the refractory.

- Refractory layers installed in the rotary flange in order to enlarge the duct life time

- Dirt scraper installed at the bottom of the airlock to avoid dirt build-up around torch

- Bi-colour pyrometer installed in the Plasma furnace to improve the temperature control in the furnace.

- Installation of automatic connection plate to reduce the torch changeover time

- Installation of back-up resin cartridge to assure proper de-ionization water features

- Installation of a 0.01 μm filter for oil mist.

- Installation of vent valves on torch starter.

- Restriction of hose lengths by the use of rigid piping and keeping starter hoses under residual pressure to reduce the reaction time of torch starter.

- Installation of HVAC system in the electrical room to avoid overheating. This lesson learned is applicable to all the facilities not only to the Plasma system.

- Installation of a cover on the tap hole instead a plug avoiding the blockage of the pouring hole.

Materials: refractory material used in the Plasma furnace and rotary flange is according to the wide experience of EUROPLASMA. The selection of the refractory material was developed taking into account operation experiences and lessons learned in other facilities as well as the PMF Kozloduy process particularities.

Maintenance practices:

- During the design phase, all required maintenance practices have been considered in order to assure the easy and safely maintenance during the lifetime of the facility. This lesson learned is applicable to all the facilities not only to the Plasma system.

- Refractory installation procedures and inspections for the PTC, required to assure a proper refractory installation, are based on wide experience of EUROPLASMA. The operation and maintenance manuals applicable to Kozloduy PMF will be developed in accordance with these experiences and lesson learned.

4.3 Lessons Learned and Operational Experience applicable to the Slag Collection system

Design Improvements: following lessons learned mainly gained in EL CABRIL have been taking into account in the Kozloduy PMF design:

- CML Hydraulic cylinder synchronization by means of chains instead by means of proportional valves to assure a proper synchronization

- Installation of counterbalance valves in the hydraulic system.

- Inverted racks used in the lift and unmold gates avoiding dirt.

- Installation of vacuum circuit to assure that the inflatable joint recover original shape after actuation.

SM and CM Design: the designs of the SM and CM for the Kozloduy PMF are based on the existing SM and CM used in ZWILAG (section 4.2). ZWILAG cools down the molten slag using equal moulds to those designed for the Kozloduy PMF. ZWILAG has not had any issue with these moulds.

Maintenance practices: According to the existing operational experience, in order to reduce the personnel exposures times and doses, and to reduce the contamination risk, it is recommended to make all equipment subject to maintenance accessible from outside the confinements. This recommendation has been followed in the SCC design and therefore the maintenance of all components could be done from outside the chamber as much as practicable. This lesson learned is applicable to all the facility not only to the SCC system.

4.4 Lessons Learned and Operational Experience applicable to the STC with off-gas treatment system

Design Improvements: following lessons learned mainly gained in CILVA (section 4.1) have been taking into account in the Kozloduy PMF design:

- Installation of frequency controlled fans to improve the control of the under-pressure

- Installation of independent alarm loop to the control water level loop.

- Availability of compressed air in emergency conditions.

- Installation of vibration motors in the hoppers of the Bag-house filter units in order to avoid bridge building of ashes.

- Installation of heating units in the Bag-house filters in order to avoid condensation.

Materials: the materials selected for the different main equipment of the STC with off-gas treatment system have been selected taking into account the operational experience of CILVA (section 5.1) and ZWILAG (section 5.2). CILVA have had several events due to material corrosion. These events were solved in CILVA changing the affected equipment by a new one, manufactured with an appropriate material. For the Kozloduy PMF, the materials have been selected to avoid all these problems. In particular, the material and coating of the bag-house have been selected equal to those used in CILVA because, after more than 15 years of operation, it has not been occurred any issue or problem, therefore there is a proven operational experience that advice to use the same material and coating. Additionally, the selection of synthetic material for the scrubber tower is based on the wide-world experience of this kind of towers in incinerators; in particular CILVA (section 4.1) and ZWILAG (section 6.2) facilities have their scrubber tower manufactured also in synthetic material without any issue in all their operation life.

4.5 Lessons Learned and Operational Experience applicable to the Continuous Emission Monitoring (CEM) system

Equipment Selection: the CEM equipment for the Kozloduy PMF project has been selected based on very high reliability and proven technology. ACF-NT is a well known gas analyser system with lots of experience in various applications all over the world. It was the first FTIR system getting an approval for emission monitoring in Germany and Europe. This kind of CEM is in operation in a lot of industries with excellent availability and reliability, in particular the ACF-NT has been checked (with successful fulfilment of tests) by the international certifying organism TÜV (refer to section 1.1.3.10 of Design Package I-270-DP-0118).

Cleaning/Maintenance practices: one of the main benefits of the use of the ACF-NT in this kind of applications is derived from its low requirements in terms of calibration routines (thanks to the FTIR measurement principle, leaving the spectrometer free from drift), as well as its low maintenance due to the minimal amount of moving parts.

4.6 Lessons Learned and Operational Experience applicable to the Control System

Control system Architecture: according to the experience of CILVA (section 5.1) and ZWILAG (section 5.2) facilities, Kozloduy PMF has been designed based on a PLC system with high degree of automation. The control system requires minimum operator intervention to maintain the process. Therefore human errors are minimized.

Relay Cabinet: according to the experience of CILVA (section 5.1) in order to assure that the PMF can be stopped in case of PLC blackout/failure, a conventional Relay Cabinet is installed. This cabinet can start directly the most important motors (extraction fans, boiler pump, circulation pump of scrubber unit, cooling pump of plasma torch) in order to keep the integrity of the system (under pressure, heat evacuation, cooling down of flue gasses) and to go to a SSD. On the same relay cabinet the important indicators are also visualized. This relay cabinet not only contributes with a redundant way of shutting down the facility, but also provides diversity, as this shutdown will be carried on by means of a completely different technology.

Alarm levels: according to the experience of CILVA (section 5.1) and ZWILAG (section 5.2), two independent level alarms have been implemented. Level 2 corresponds to the warnings alarms indicating the operator that a parameter is out of the normal range, as well as level 1 alarms trigger the SSD procedure. With these two levels of alarms, a great number of plant stops are avoided and therefore the productivity and reliability of the Plant are increased.

Video Camera Supervision system: according to the experience of CILVA (section 5.1) and ZWILAG (section 5.2), a video camera system to permit the remote monitoring of the key process points is recommended in order to reduce the operational doses absorbed by the operators. The Project includes a CCTV system to monitor following points: Slag Collection Chamber (4 cameras), Pouring Confinement (2 cameras), Plasma Furnace (2 cameras), Tap hole (1 camera) and Shredder unit (1 camera).

5. Reference Facilities

5.1 'CILVA' Facility

CILVA facility is a treatment facility for low level radioactive waste. It is located at Belgoprocess site (Belgium) and it consists of waste reception equipment, an incinerator facility, a super-compaction facility and a cementation facility.

The PMF off-gas treatment system configuration is based on the experience of the CILVA system in operation from May 1995. CILVA facility has also several grippers in operation that are used to handle different types of containers, equal to the grippers that will be used in PMF.

5.2 'ZWILAG' Facility

Low and medium-level radioactive waste from Swiss nuclear power plants as well as from medicine, industry and research are processed in ZWILAG. The site also provides interim storage for all types of radioactive waste and spent fuel assemblies from Swiss nuclear power plants. ZWILAG took the decision to embrace a new, state-of-the-art method for the incineration of radioactive waste. Radioactive waste is no longer incinerated in a conventional manner; instead it is thermally decomposed or melted at high temperatures by a high-output plasma burner. This metallurgy-derived plasma process on the one hand allows combustible materials to be processed, but on the other also permits the fusion of metallic components, concrete etc. The same process steps can be used to vitrify both organic and inorganic materials into residual materials suitable for storage in final repositories. In fact, ZWILAG is the most experienced plasma facility for the treatment of radioactive waste in the world with a wide experience in industrial operation.

5.3 'INERTAN' Facility

INERTAN is a Plasma melting facility located in France to treat asbestos waste in operation since 1997 (24/71). It has a capacity of 30 tons/day.

INERTAM facility has a Plasma system similar to Kozloduy PMF with following elements: Plasma furnace with cooling system, Plasma heating system (torch, automatic connector, bracket, PHS cooling, plasma air supply, plasma power system and hydraulic module), and auxiliary burner.

5.4 'CENON' Facility

CENON is a Plasma melting facility located in France in operation since 1998 (24/7). It treats fly ash from the incineration of household waste (120000 tons/year) and sludge (18000 tons/year). CENON Facility has a Plasma system similar to Kozloduy PMF with following elements: 1 24 hours per day, 7 days per week.

Plasma furnace with cooling system, Plasma heating system (torch, bracket, PHS cooling, plasma air supply, plasma power system and hydraulic module) and auxiliary burner.

5.5 'KAKOGAWA' Facility

KAKOGAWA is a Plasma melting facility located in Japan in operation since 2003 (24/7). It treats ashes from a fluidized bed incinerator (10000 tons/year).

KAKOGAWA Facility has a Plasma system similar to Kozloduy PMF with following elements: Plasma furnace, Plasma heating system (torch, automatic connection, bracket, PHS cooling, plasma air supply, plasma power system and hydraulic module), and auxiliary burner.

5.6 'SHIMONOSEKI' Facility

SHIMONOSEKI is a Plasma melting facility located in Japan in operation since 2002 (24/7). It treats fly ash and boiler ash from a waste incinerator (household waste: 140000 tons/year).

SHIMONOSEKI Facility has a Plasma system similar to Kozloduy PMF with following elements:

Plasma furnace, Plasma heating system (torch, automatic connection, bracket, PHS cooling, plasma air supply, plasma power system and hydraulic module), and auxiliary burner.

5.7 'IMUZU' Facility

IMUZU is a Plasma melting facility located in Japan in operation since 2002 (24/7). It treats fly ashes from a fluidized bed incinerator (household waste: 50000 tons/year).

IMUZU Facility has a Plasma system similar to Kozloduy PMF with following elements: Plasma furnace, Plasma heating system (torch, automatic connection, bracket, PHS cooling, plasma air supply, plasma power system and hydraulic module), and auxiliary burner.

5.8 'MAIZURU' Facility

MAIZURU is a Plasma melting facility located in Japan in operation since 2003 (24/7). It treats fly ashes and boiler ashes from a waste incinerator (domestic waste: 80000 tons/year). MAIZURU Facility has a Plasma system similar to Kozloduy PMF with following elements: Plasma furnace, Plasma heating system (torch, automatic connection, bracket, PHS cooling, plasma air supply, plasma power system and hydraulic module), and auxiliary burner.

5.9 'YONGIN' Facility

YONGIN is a Plasma melting facility located in South Korea in operation since 2009 (24/7). It treats fly ash from the incineration of wastewater treatment plant sludge (5000 tons/year).

YONGIN Facility has a Plasma system similar to Kozloduy PMF with following elements: Plasma furnace with cooling system, Plasma heating system (torch, automatic connection, bracket, PHS cooling, plasma air supply, plasma power system and hydraulic module), and auxiliary burner.

5.10 'EL CABRIL' Facility

EL CABRIL is the installation used for the disposal of low and intermediate level radioactive wastes in Spain. It is designed to cover all the current disposal needs for this type of wastes, including those arising from the dismantling of nuclear power plants. The facility has two platforms for the disposal of low and intermediate level radioactive waste and another with specific structures for very low level wastes. In addition, the facility has the resources required for the treatment and conditioning of wastes requiring such processes.

Equipment already in operation in EL CABRIL with successful experience has been used in the Kozloduy PMF Project:

- A pushing device like the one designed for the SCC was installed in EL CABRIL pushing super compacted bundles. It remains in operation with no incidents since 2002. Another installation with similar mechanism is the Horizontal Displacement Truck. This system is installed in EL CABRIL as well as in the Solidification Mobile Facility of CIEMAT in 1989, and in several NPPs.

- A crane very similar like to one designed for the SCC is installed in EL CABRIL, in particular the crane has also the inverted rack.

- A gripper, similar to the one designed for the SCC, is working with no problem picking Cast Iron Shielding in EL CABRIL. This gripper has the same hydraulic actuator and similar design of sticks.

- A similar inflatable joint, to the one designed for the SCC, is installed in the laboratory of EL CABRIL without any problem.

- Suction cups similar to those foreseen for DLS of the SCC are installed in EL CABRIL since 1996 without major problems or replacements. Additionally, similar suction cups have been also installed in TRILLO NPP and VANDELLOS I NPP also without major issues.

5.11 CEM References

The same CEM system is already installed in various applications all over the world.

Following you can find the list of incinerator types used as testing facilities to proof the availability of CEM equipment (refer to section 1.1.3.10 of Design Package I-270-DP-0118 for additional details):

- Industrial sewage sludge incinerator
- Municipal waste incinerator
- Biomass incineration

Additionally, following incineration facilities of conventional waste have in operation a CEM system equal to the system designed for Kozloduy PMF without remarkable problems:

- LAB SA facility located in France, operative since 2005.
- CANTABRIA INCINERATOR facility located in Spain, operative since 2004.
- CORY ENVIRONMENTAL facility located in UK, operative since 2010 for municipal waste incineration.
- VEOLIA ENVIRONMENTAL SERVICES facility located in UK, operative since 2010 for municipal waste incineration.
- E.ON facility located in UK, operative since 2009 - CHP Plant.
- PUREPOWER HUNTINGDON LTD facility (UK) located in UK, operative since 2009 - Waste Recycling
- SCOTTISH LEATHER GROUP facility located in UK, operative since 2009 for animal waste incineration.
- TRACKWORK LTD facility located in UK, operative since 2009 for wood waste incineration.
- BIOFLAME LTD facility located in UK, operative since 2007 for wood waste incineration.
- INSTITUTE FOR ANIMAL HEALTH facility located in UK, operative since 2006 for animal waste incineration.
- SITA UK LTD facility located in UK, operative since 2006 for municipal waste incineration.
- SUSSEX WASTE RECYCLING LTD facility located in UK, operative since 2008.
- AISH SERVICES LTD facility located in UK, operative since 2007 for animal waste incineration.
- FORMICA LIMITED facility located in UK, operative since 2007 for chemical waste incineration.
- JOSEPH MITCHELL facility located in UK, operative since 2007 for animal waste incineration.

- ORAN GROUP facility located in UK, operative since 2007 for animal waste incineration.

- FACULTATIVE TECHNOLOGIES/VLA WEYBRIDGE facility located in UK, operative since 2005 for animal waste incineration.

- SHETLAND ISLANDS COUNCIL facility located in UK, operative since 2005 for municipal waste incineration.

6. CONCLUSIONS

All collected lessons learned and operational experience have been taken into account in the Kozloduy PMF Project to assure that all applicable technical solutions as well as BAT have been implemented.

11.3.2 IAEA recommendations

Storage of low and medium active waste in an appropriate storage facility is not alarming and is currently practiced by several countries. It should be noted that all European countries that operate nuclear power plants and those that use radioactive materials or ionizing sources, have signed the ”Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management” of IAEA.

In Annex 3 of the IAEA Safety Guide about design and operation of RAW incineration facilities [21] basic requirements for off-gas treatment concepts are described. It is stated, that the design depends on the waste input, the incineration conditions and regulatory requirements. This system is for the protection of the environment against radiological and conventional air pollutants. Typical or basic elements of such systems are filtration, separation and wet scrubbing. It is stated that wet scrubbers can be used to remove corrosive gases and that they exhibit the highest decontamination factors for the total radionuclide. Safety Guides contain recommendations on the basis of international experience.

The Safety Standard about predisposal management of low and intermediate level radioactive waste [22] requires scrubbing and the use of Bag and HEPA filters for off gas treatment systems for waste incineration. The used filters must be compatible with the treatment and conditioning process.

The IAEA TECDOCs are documents for information. The TECDOC-1492 about waste management at WWER nuclear power plants [23] covers the important aspects applicable to the improvement of waste management at WWER NPPs.

It is stated that in comparison to western PWR the amount of accumulated waste is very high and concepts for waste minimization are urgently necessary.

In point 7 of this document (strategies and methods for improvement for waste minimization) the evaluation and implementation of advanced volume reduction and conditioning technologies is given.

TECDOC-1527 [24] describes the application of thermal technologies for volume reduction and conditioning of radioactive waste.

In part 5 of this document the plasma technology is assessed, on page 47 it is written:

"In contrast to radioactive waste incineration and other technologies which rely on the combustion of an organic fuel, plasma torches enable thermal conversion to occur in a relatively small volume with high efficiency."

The advantages are described on page 50 with the following quotations:

- One single process can treat the waste as generated (i.e. no prior treatment is necessary). This reduces the infrastructure costs and reduces the radiation exposure to personnel from duplicative handling of the waste.
- The final waste form is robust, free of organic material, and suitable for long term storage and disposal.
- Volume reduction factors can range from 6:1 (typical ZWILAG results) for waste containing mostly metal and debris (including the waste containers) to 10:1 for treatment of mixed waste (typical RADON results) and to more than 100:1 for primarily organic waste.
- Since the heat source is plasma instead of fossil fuels, there is less production of certain flue gases and the greenhouse gas CO_2.

As limitations are stated expenses related to construction and operation and limited plant experience (only ZWILAG and RADON).

Due to environmental issues is written, that an optimal off-gas treatment system has to achieve the regulatory limitation values for both, nuclear and conventional emissions.

It is stated about the existing PMFs, ZWILAG and RADON: "the installations existing to date meet the highest environmental and regulatory standards of the day."

Concerning the energy consumption it is stated that it is high in comparison to other methods, but on the other hand the product is suitable for disposal in a final storage.

11.3.3 Best Available Techniques according to the IPPC Directive

For waste treatment two BREFs are existing, Waste Treatment and Waste Incineration [25]. The treatment of radioactive waste by incineration, vitrification or use of plasma is not listed in Annex I of the IPPC Directive.

For general or fundamental requirements for the whole RAW management the document [28] about BAT for the Management of the Generation and Disposal of Radioactive Wastes can be taken into account. This document was elaborated in the U.K., but interesting for assessment, as the term BAT (EU law) is applied for RAW management. Similar documents from other EU Member States or IAEA Members are unknown.

As stated in section 2.2.4 of [28], the selection of the most appropriate abatement technology to reduce disposals shows how the environmental, social and economic aspects of sustainable development need to be balanced. For example, there would be no overall benefit to the environment if, as a result of a new abatement process, a plant emitted large quantities of carbon dioxide or toxic (but non-radioactive) substances into the environment, resulting in environmental harm equal to or greater than that avoided by reducing the radioactive discharges.

BATs are shown in fig. 11.3.3-1. As can be seen from that figure, the IP is in line with the best available technical and principles for waste management.

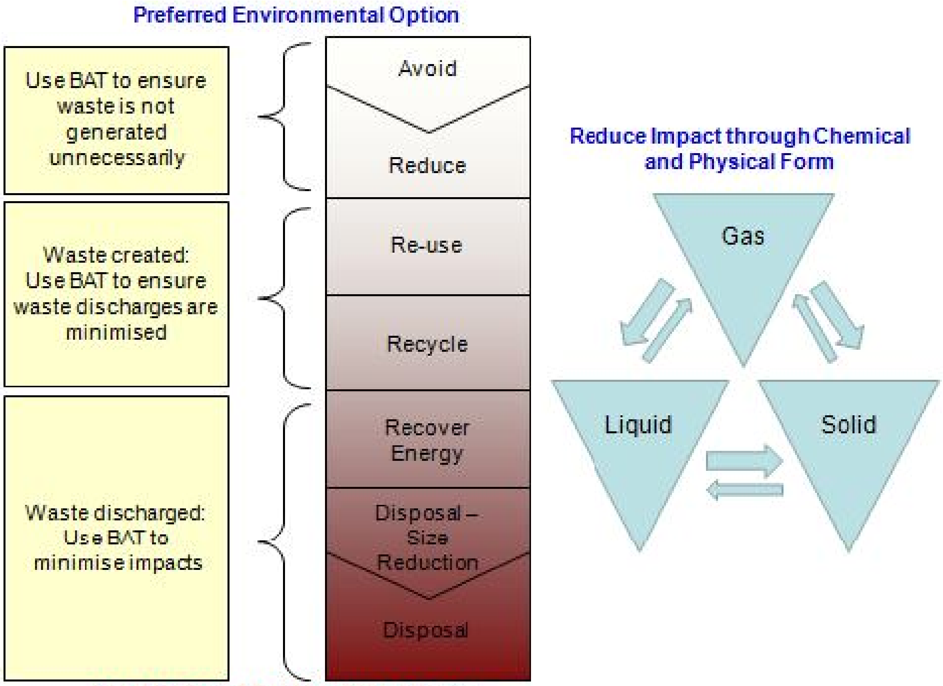

Fig. 11.3.3-1 The best available techniques and principles for waste management

In accordance with Section 4.6 of [28] on BAT for the Management of the Generation and Disposal of Radioactive Wastes the Environment Agency states in its guidance on Principles of Optimization: “The operator should have regard to the use of standards, guidance and relevant good practice. This applies to all aspects of operation, including matters such as sampling and monitoring, management systems, maintenance, record keeping etc. Sources of such guidance and good practice include:

- Government Policy;
- Environment Agency Guidance (including joint guidance with the HSE/SEPA);
- Codes of Practice;
- Standards (whether international or national or trade);
- Company standards/procedures; and
- Working practices, processes and techniques.

“Operators may seek to argue that the adoption and implementation of regulatory guidance and relevant good practice represents BAT without the need for more detailed consideration of options appraisal and optimization. This approach is acceptable providing that the operator demonstrates that the guidance and good practice is relevant, up to date and fully applicable at the facility and circumstances in question. This forms part of a proportionate approach to applying and demonstrating BAT. Similar guidance is offered by HSE”.

At present, EIA reports in order to assess alternatives, including the proposed Alternative 2, an analysis and assessment of the impact on humans and the environment components, have been made.

"In order to identify a preferred option from a range of alternatives, the benefits and detriments for each approach can be evaluated against appropriate performance measures or attributes (which may be grouped as higher level criteria). Key areas to consider when defining criteria and attributes include:

- Impact of routine discharges and disposals on the public and the environment;
- Impact of potential accidents on the public and the environment;
- Occupational doses; and,
- Waste arising".

Detailed technical requirements are described in the IAEA documents, mentioned above (e.g. scrubber and HEPA filter for minimization of radionuclide emissions).

The BAT assessment and definition in the BREF for waste incineration [25] must be used for the comparison with the PMF project in relation to the minimization of emissions of conventional air pollutants. In [25] the plasma technology is described in chapter 2 (applied techniques) but not assessed in chapters 4 and 5, where the BAT criteria are considered. Thus general BAT criteria and criteria related to the requirements for off-gas treatment can be taken into account. Formal the BREF is a tool for the licensing authority to determine the BAT in specific cases. In chapter 4 the techniques which are most relevant for determining BAT and BAT based permit conditions are described in detail.

The following parts of chapter 4 are in harmony with the PMF technology:

- Shredding of packaged and drummed waste (4.1.5.3);
- Pre dusting stage by bag filters (4.4.2.1);
- Selection of filter bag materials; PTFE with excellent resistance for acid and alkali (4.4.2.4);
- Wet scrubbing, highest efficiency for acid gas absorption (4.4.3.1);
- NaOH as alkaline reagent in wet scrubbing, highest reactivity for acid gases;
- Selective catalytic reduction (SCR) after dedusting and acid gas cleaning (4.4.4.1);
- Combination of dust removal + SCR, giving the lowest overall emissions of PCDD/F (4.4.5.3);
- Separate evaporation of wet scrubber effluent (4.5.15).

Based on the information from chapter 4 the BAT criteria are stated in EIAR chapter 5.

In the following part all PMF related criteria are listed, mainly general criteria and criteria for the off-gas treatment process as can be seen in table 11.3.3-1.

Table 11.3.3-1 List of some PMF relevant BAT criteria

BAT No.	Short description
3	Maintain all equipment in good working order
4	Quality controls over the waste input
5	Storage of waste input according their risk assessment
9	Clear labeling of wastes stored in containers

BAT No.	Short description
10	Plan for prevention, detection and control of fire hazards
19	Use of optimized operating conditions
26	Optimization of installation energy efficiency and energy recovery (1)
32	Minimization of overall installation energy demand (2)
35	Overall flue gas treatment which provides operational emission levels listed in table 5.2 (3)
48a	Use of physical/chemical treatment of the scrubber effluents

Remarks: (1) + (2) The SCR technology requires the reheating of the flue gas (4.4.4.1). (2) See table 2.4-2 below.

Interesting for the assessment of best practice is the recast of the IPPC Directive, the Directive on industrial emissions [26]. Chapter IV (articles 42-55) contains special provisions for waste incineration plants and waste co-incineration plants.

It has to be taken into account, first, that this Directive is not valid at present, as the deadline for transition to national law of the Member States starts 2013; and second, that according to article 42 the treatment of radioactive waste is excluded from this Directive.

11.3.4 Assessment and comparison of the emission values for the Kozloduy PMF, the ZWILAG PMF, the CILVA incineration facility

The CILVA is a RAW incineration facility. The development of the off-gas treatment for the Kozloduy PMF was based on technology and experience from this facility.

Radiological emission values

In table 11.3.4-1 is given comparison between approved annual limited value for β/γ aerosols CILVA incineration plant and ZWILAG Plasma Melting Facility with the guaranteed values of the Kozloduy NPP PMF.

Table 11.3.4-1 Approved annual limited values for β/γ aerosols CILVA incineration plant and ZWILAG Plasma Melting Facility in comparison with the guaranteed values of the Kozloduy PMF

Facility	Annual mass flow (t/a)	Approved annual emission, Bq	Real annual emission, Bq	Guaranteed annual emission, Bq
CILVA	**ca. 200 (1)**	**1E+8 (1)**	**1E+5**	
ZWILAG	**200**	**1E+9 (2)**	**ca. 5E+5 (3)**	
Kozloduy PMF	**250**			**6.03E+6**

(1) *evaluation from publication [47]*
(2) *approved annual emission for all ZWILAG facilities, but the Plasma plant is the main emitter*
(3) *see [57]*

- These facilities are comparable due to the annual input mass flow and the kind of input material: operational RAW from NPPs.
- The guaranteed annual emission of the Kozloduy PMF is main below the

approved annual emissions of the named comparable facilities

- In these facilities the last parts of the off-gas treatment are the same: HEPA filters and alkaline scrubber, thus it can be expected that the real annual emissions from the Kozloduy PMF are below the guaranteed annual emissions.

Conventional air pollutant emission values

The conventional emission values of this facility can be used for comparison because the PMF off-gas treatment is based inter alia on the experience from the CILVA system. In the following table 11.3.4-2 the emission limit values stated as in Annex 4, part 3 of the EU Directive 2010/75/EU [26] and the emission levels of BREF [25] (chapter 5, table 5.2) waste incineration are compared with the designated values for the PMF [27]. The emission levels from the BREF are not defined as emission limit values, but as "operational performance levels that shall normally be anticipated from the application of BAT".

Table 11.3.4-2 Approved annual limited values for air pollutants CILVA incineration plant and ZWILAG Plasma Melting Facility in comparison with the expected values of the Kozloduy PMF

Pollutants	**BREF**	**Directive 2010/75/EU**	**ZWILAG approved**	**ZWILAG (annual average)**	**CILVA (annual average)**	**Kozloduy PMF [55] (guaranty value)**
	Daily (1) average values mg/m³	***Daily (1) average values mg/m³***	***Daily (1) average values mg/m³***	***Daily (1) average values mg/m³***	***Daily (1) average values mg/m³***	***Daily (1) average values mg/m³***
Total dust	1-5	10	10	2.58	0.56	< 1
CO	5-30		50	3.41	25	< 5
TOC	1-10	10	20		6	< 1
HCL	1-8	10	20	0.02	0.36	< 1
HF	<1	1	2	0	0.03	< 1
SO_2	1-40	50	50	7.72	17	< 5
NOx	40-100	200	80	15.01	133	<100
Heavy (2) metals						
∑ Cd,Tl	0.005-0.05	0.05	0.1		<0.02	0.005
Hg	0.001-0.02	0.05	0.1	0.01	<0.01	0.005
∑ Sb, As, Pb, Cr, Cu, Mn, Ni, V, Sn	0.005-0.5	0.5	1*		<0.162	0.05
Dioxines (3) and furans [ng/m³]	0.001-0.1	0.1	0.1		0.001	0.01

(1) Conditions: 273 K, 101.3 kPa, 11 % O_2, dry gas
(2) Average values over sample period minimum 30 min. –max. 8 hours
(3) Average values over sample period minimum 6 hours – max. 8 hours
*Pb+Zn

Remarks to the table:

- Column 2: The emission levels from the BREF are not defined as emission limit values, but as "operational performance levels that shall normally be anticipated from the application of BAT".

- Column 3: The values of the EU Directive must be changed to national law of the Member States in 2013, thus they are not valid at present. But the limit values are the same as required by the Bulgarian Regulation No. 6 (waste incineration) [48]. However the Investor has requested that the requirements of all applicable EU Directives shall be fulfilled by the design.

- Column 4: Limit values according to the Swiss Clean Air Act (Appendix 2, 71 Facilities to burn municipal and special waste).

- The comparison of the expected values for the Kozloduy PMF [55] (column 7) with the operational values from ZWILAG and CILVA (columns 5 and 6) demonstrates the potential for emission limitation. But the direct comparison of the operational values (after a long optimization period) with the guaranteed values is not possible.

As result of the assessment of the above values can be summarized that all of the Kozloduy PMF conventional emission values fulfill the limit values of the Bulgarian law related to waste incineration [48] and the new EU requirements [49].

In comparison with the respective BREF (recommendation) values, to use as main BAT comparison basis, the Kozloduy PMF fulfills the BAT requirements in all cases.

Conclusions:

1. The proposed Alternative 2 complies with BAT in all aspects, management of RAW, emission limitation of radionuclide and emission limitation of conventional air pollutants.

2. In the preparation of EIA recommendations from Best Available Techniques (BAT) for the Management of the Generation and Disposal of Radioactive Wastes [28] are used to assess the safety, technical characteristics of the PMF, and environmental and socioeconomic impacts.

3. The selected technology corresponds with the recommendations made by the IAEA for similar facilities for the conditioning of radioactive waste with high coefficient of volume reduction.

4. During the preparation of EIA R chapter 2 are used fulfilled analysis, assessment and conclusions concerned the BAT for RAW treatment.