Technical Note
ERDO-WG - LWC project – Task1
Report on main Legacy Waste streams in the interested countries

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1 INTRODUCTION

The high-level objective of the ERDO-WG Legacy Waste Characterization (LWC) project is sharing information and methodologies for a better characterization of Legacy Waste in view of possible future management activities and acceptance for storage or disposal into national/multi-national facilities.

For the purpose of the present project, Legacy Waste is defined as: radioactive waste generated in past activities (energy production, medicine, research, industry) which has been treated and conditioned according to the rules in force at the time or simply stored pending a suitable management solution; such waste is often lacking sufficient physico-chemical-radiological characterization data for envisaging possible re-treatment/re-conditioning processes in line with current regulatory requirements and/or checking compliance with Waste Acceptance Criteria (WAC) of storage/disposal facilities.

The first Task of the project consisted in exploring the inventories of the main Legacy Waste streams[1] generated to date in the interested countries.

2 SCOPE

The analysis of the Legacy Waste streams inventory in the interested countries aims at:

- putting into evidence common waste streams and identifying analogies/differences in classification, characterization, future treatment/conditioning, disposal destination;
- highlighting common weakenesses or strengths relevant to the characterization of such waste which may respectively jeopardize or promote shared management initiatives up to disposal;

[1] For the scope of the present project the term 'waste stream' is used for grouping waste from individual or different sources based on the waste's physical state (liquid, gaseous, solid), type (dry solids, resin, sludges, slurry, metal, combustible, compactable, …), properties (radiological, physical, chemical,…), in view of possible pre-treatment, treatment, conditioning process options to be applied to the group.

- formulating preliminary considerations on characterization of these waste streams for optimizing their management/disposal.

3 SURVEY OF THE LEGACY WASTE STREAM INVENTORIES

A dedicated Excel spreadsheet for gathering the needed characteristics of the legacy waste streams was arranged and circulated among the interested organizations of 7 countries:

- NES (Austria)
- FUND-NEK (Croatia)
- DD (Denmark)
- NCSRD (Greece)
- SOGIN (Italy)
- COVRA (Netherlands)
- NND (Norway)

ARAO (Slovenia) declared no Legacy Waste streams in the country.

The first evidences form the collected inventories are the similarities in many waste streams characteristics. So the single inventories have been arranged in a comparison table (in annex) by grouping the various kinds of legacy waste streams into 13 as homogeneous as possible groups[2].

In this way it was possible to highlight the most important features and common aspects (Evidence), critical elements (Weakenesses), favorable elements (Strengths) related to the definition of an adequate characterization strategy with the aim of facilitating their future management up to disposal (possibly using shared facilities).

The waste stream classification is based on each country's scheme; the classifications of a similar waste stream in different countries are therefore assumed to be not always

[2] The streams are often composed by several different kinds of waste with different properties; grouping has been performed selecting the main characteristic of the stream potentially impacting on the safety of future pre-disposal and disposal activities (e.g. metallic waste containing also PVC have been included in the 'Solid organic waste' group instead of the 'Metals' group, because PVC may cause degradation and gas generation)

comparable. For the scope of the present report, it is assumed that VLLW and LLW can be disposed of in near surface repositories (although some countries have defined a disposal strategy that provides for their disposal in deep repositories), while ILW shall be disposed of in deeper repositories (i.e. medium depth and deep geological repositories, defined as 'Other' in the survey table, with respect to 'Near surface' disposal facilities)[3].

3.1 Disused Sealed Radioactive Sources (DSRS)

Evidence: DSRS, common to 5 over 7 countries, are heterogeneous in types, origin and radionuclide content; the classification ranges from LLW to ILW. The packaging is performed generally using metallic containers (in one case plastic or wooden containers), shielded in some cases. The same container may host different sources.

In many cases DSRS are simply packaged (no encapsulation in cement or other matrices). Management in all countries is planned on the basis of classification; in particular, except countries envisaging the realization of a single geologic repository, all countries foresee disposal of LLW (short lived) sources in near-surface repositories. The storage of DSRS is well defined by all countries, while the pre-disposal conditioning process is not always established. Many countries foresee a process based on cementation or direct packaging in high integrity containers potentially suitable for disposal.

Weaknesses: classification of DSRS is a critical point as it is not defined in all countries and when indicated, the relevant classification criteria may differ (probably due to the lack of standardization or for the different disposal solution used), making difficult looking for similarities or possible sharing of waste management facilities.

The reliability of the radiological characterization, when available, is generally reported as 'low' or 'medium' and this may create difficulties in checks for compliance with WAC. Definition of a radiological characterization method is disadvantaged by the fact that the same container usually hosts different sources and in some cases such sources are already immobilized by cement thus potentially requiring re-treatment for retrieving the

[3] The HLW category was excluded by the survey

sources and suitable characterization for conditioning and acceptance to disposal. In case of alpha sources the difficulty is mainly linked to the impossibility of carrying out non-destructive measurements.

Strenghts: When DSRS are simply packaged, future activities of retrieval, characterization, treatment and conditioning are easier. Chemical characterization is often lacking but, for this type of waste, it is not highly relevant. Common features and similarities among the waste streams of this group suggest possible synergies in sharing pre-disposal and disposal solutions.

3.2 Mixed Solid Waste

Evidence: This group, common to 6 over 7 countries, is constituted by a considerable variety of waste streams containing diverse solid materials (clothing, paper, glass, metal, small sources, etc.); in some cases the presence of organic materials (wood or organic specimen) or reactive/degrading agents (i.e. aluminum) is reported.

Most of the waste streams are classified as LLW and simply packaged; some of them are in a “raw” state and other treated or conditioned, requiring further treatment or re-conditioning. They are mainly contained in 200 l metal drums, largely intended for near-surface disposal. The processes of treatment and conditioning are mostly defined in conceptual terms. The following pre-treatment/treatment processes are foreseen: sorting, inceneration, supercompaction, packaging or packaging in high integrity container without matrix (in case of ILW).

Weaknesses: Characterization is often reported with ‘low’ reliability level. In one case, the classification is not indicated (due to lack of a national classification scheme). Characterization difficulties are also due to waste heterogeneity within the same containers, which make even more difficult sorting, waste treatment and checking for compliance with WAC.

Chemical characterization is lacking. It’s necessary to define chemical characteristics of waste, and hence establish suitable chemical characterization methodologies, in order to qualify the possible conditioning/re-conditioning process.

The extreme variety of waste makes difficult looking for shared waste management solutions.

Strenghts: Treatment and/or conditioning processes of this waste stream are indicated by almost all countries (radiological and chemical characterization can be performed during re-treatment and sorting).

3.3 Powdery waste

Evidence: This waste group, common to 4 over 7 countries, consists of solid waste streams, such as contaminated soil, metals, ashes and filters in granular form (zeolites). Contaminated soil is the common waste stream in all countries. Classification is LLW for most of the reported waste and their final destination is near-surface disposal (except one case of ILW due to long lived aplha activity concentration expected to be > 400 Bq/g). They are mostly contained in 220 l drums and are expected to be conditioned by cementation.

Weaknesses: Waste are not always characterized and the reliability of the characterization is 'low'. The alpha emitters content in some waste streams could invalidate the current declared classification. The treatment and/or conditioning processes are not always envisaged; in one country such processes are in course while in others are only in concept phase. Except one case, the declared quantities of contaminated soil are relatively low, but the remediation of contaminated sites may generate larger quantities in the future.

Strenghts: considering that radiological and chemical characteristics are presumably homogeneous in individual containers, sampling should be relatively simple facilitating the subsequent characterization. Both homogeneous and heterogeneous conditioning processes are generally feasible. One country declares that conditioning may be performed by means of a new transportable system. The similarities of the waste streams declared by the countries (contaminated soil) may facilitate the search of possible pre-disposal shared solutions.

3.4 Sludges

Evidence: This waste group, common to 5 over 7 countries, consists of sludges deriving mainly from water treatment processes, classified as VLLW, LLW and ILW (due to alpha contaminants). Sludges are contained in different containers (drums, boxes and tanks); most of them are still in raw conditions, some of them partially already conditioned in bitumen or cement. Except countries envisaging the realization of a single geologic repository, they are mainly intended for near-surface disposal.

Weakness: Radiological characterization is lacking (in one case the classification is missing, due to the lack of a classification scheme in the country). Chemical characterization is missing or at 'low' reliability level.

Some waste streams contain degrading and toxic substances to be carefully considered in order to define the best treatment process. Sludges already conditioned in bitumen and cement will need to be re-treated, characterized and re-conditioned for possible disposability.

Strenghts: Radiological characterization methodology is indicated by almost all countries: non-destructive gamma measurements, sampling and subsequent gamma and beta/alpha characterization on the samples. One country declares that conditioning may be performed by means of a new transportable system. The similarities of the waste streams declared by the countries and the current raw status of most of them may facilitate the search of possible shared solutions.

3.5 Ion exchange resins

Evidence: This waste group, common to 5 over 7 countries, consists of ion exchange resins used in the purification process of water from various plants. They are classified as VLLW, LLW and ILW, packaged in drums of several different dimensions, being intended for both near-surface and deep repository. In all contries the resins shall be treated and conditioned for disposal; in three cases the treatment processes are defined (thermal process, Wet Oxidation process, incineration); in two cases resins are already conditioned with bitumen and concrete but a future re-treatment/re-conditioning process shall be defined

Weaknesses: In most countries the radiological characterization is at 'low' level of reliability and suitable sampling/characterization is foreseen (in one case the classification is missing, due to the lack of classification scheme in the country). Chemical characterization is missing too. Difficulties are linked to the need of recovering the resins in the cases where they are already immobilized.

Strenghts: Similarities of ion exchange resins streams and common needs of characterization and treatment/re-treatment for disposal suggest possible synergies in pre-disposal shared solutions. The declared new treatment processes in two countries may constitute the basis for such synergies.

3.6 Solid organic waste

Evidence: This waste group, common only to 3 over 7 countries, includes few waste streams but of very different types, classified as VLLW, LLW and ILW and declared to be disposed of both in near-surface and deep repositories. Reported treatments include supercompaction and incineration, while for waste streams containing PVC, often mixed with other waste (e.g. metals), the treatment is not defined yet.

Weaknesses: The radiological characterization is not always reported (in one case the classification is missing, due to the lack of classification scheme in the country). The chemical characterization is missing. Some streams contain potentially degrading materials to be taken into account in case of direct conditioning without pre-treatment[4].

[4] Cellulosic materials (e.g. wood) may degrade under alkaline anaerobic conditions producing soluble organic compounds that can form complexes with some radionuclides contained in the waste. These complexes may increase radionuclide migration. PVC presents high sensitivity to high energy irradiation because of the weakness of carbon-chloride bond face to carbon-carbon and carbon-hydrogen bonds

Volumes are small, so any treatment could be off-scale.

Strenghts: The small reported quantities suggest possible synergies in pre-disposal shared solutions (e.g. incineration processes).

3.7 Liquid organic waste

Evidence: This group, common to 3 over 7 countries, includes liquid waste with important organic components (i.e. oil, sludge, detergent, kerosene, solvents) generated by different nuclear practices. They are classified VLLW, LLW and ILW and are packaged in different containers: metallic drums, boxes, tanks, plastic canister. They contain Alpha, Beta and Gamma emitters radionuclides and are intended for both near-surface disposal and deep disposal. One country reports about a possible treatment of oily waste by means of absorption on innovative geo-polymers and subsequent direct conditioning with cement (R&D in course within the Euratom PREDIS project).

Weaknesses: Inadequate radiological characterization; chemical characterization is missing.

Strenghts: Easy to sample and characterize radiologically and chemically. Possible synergies in pre-disposal management thanks to R&D in course within the Euratom PREDIS project.

3.8 Graphite

Evidence: This waste group, common to 4 over 7 countries, consists of mainly graphite present in the moderators and reflectors of the reactors. Where classification is available, it is classified as VLLW, LLW and mainly ILW. Largely still present in reactor stacks. It is mainly intended for deep repository, but there are cases where it is declared as disposable in near-surface repositories.

Weaknesses: The radiological characterization is generally of low reliability (execpt in one case); sampling is generally foreseen except one case where calculation is used followed by NDT for confirmation. Due to the radiological content and the embrittlement due to neutron irradiation, in some cases the graphite blocks are still in the reactor vessels and solutions are being studied to allow safe retrieval. Chemical characterization is lacking except in one case.

No country has already defined the future treatment process, confirming that for this waste stream the applicable solutions are still being studied.

Strenghts: Ease of characterization with destructive measures, at least for the moderator. Synergies in retrieval, pre-disposal management routes and shared disposal solutions are being explored within international R&D projects.

3.9 Metals

Evidence: This group, common to 3 over 7 countries, includes activated and contaminated metals (steel, aluminum, lead) consisting of parts of the fuel elements, internal instrumentation of the reactor or objects contaminated with plutonium. Waste streams are classified as VLLW, LLW, ILW and are in some cases already conditioned with cement; in other cases they are contained, in raw conditions, in containers awaiting for the definition of a treatment process**.** They are intended for disposal both in near-surface and in deep repositories.

Weaknesses: Radiological characterization is missing or at low realiability. Chemical characterization has to be implemented by all countries in order to take into account possible toxic metals (e.g. Pb) and degrading metals (e.g. Al) before defining the most suitable conditioning process.

Strenghts: The current unconditioned state allows easy non destructive characterization or sampling. Similarities in waste streams characteristics among countries and small reported quantities suggest possible synergies in pre-disposal management routes

3.10 Alfa Bearing Solid Waste

Evidence: This waste group, common to 5 over 7 countries, includes various waste streams classified as LLW, ILW and even as HLW (in one country the classification is not indicated due to lack of classification scheme): laboratory vials containing powders, materials contaminated by Radium, Thorium, Plutonium and irradiated/non irradiated Uranium, small pieces of non-irradiated fissile material and spent fuel, high activity NORM. Not always the waste streams are packaged; when packaged, the containers are of several different shapes and dimensions and clearly not intended for long-term storage nor final disposal; also, the future treatment and conditioning is not always defined. The streams are mostly intended for deep disposal.

Weaknesses: Except one waste stream of one country, the radiological characterization is missing or at low realiability. The physical form and the radiological content of the waste streams make quite difficult defining suitable treatment and conditioning processes for the safe long-term storage and disposal. Also shared pre-disposal management solutions are not easily foreseeable.

Strenghts: Waste streams are not conditioned or immobilized, making easier future waste management activities (retrieval, sampling, characterization, treastment, etc.) to be explored as part of future Strategic Research Agenda.

3.11 Reactive metals

Evidence: This group, common to 2 over 7 countries, includes waste streams containing reactive metals such as aluminum, magnesium, zirconium, sodium and beryllium, arranged in steel containers (in one case the current packaging is not defined). They are classified as LLW and ILW (in one case the classification is missing, due to the lack of classification scheme in the country) and intended for deep disposal. Considering the extensive use of these materials in the nuclear industry, it can be assumed that the presence of these metals in the legacy waste inventories declared by the countries is much more diffused than actually recorded by the survey.

Weaknesses: In one country the characterization of these waste is of medium reliability, while it is under research in the other; besides the chemical form, not even the physical form is defined. The choice of the suitable treatment has to be carefully explored with reference to possible long-term degradation scenarios in disposal environment (e.g. gas generation).

Strenghts: N/A

3.12 Chemotoxic material

Evidence: This group, common to 5 over 7 countries, includes waste streams containing asbestos for thermal insulation, lead shieldings, materials coated with paints containing PCB and other chemotoxic materials, generally in not treated form, simply packaged in steel containers or not yet packaged. Waste streams are classified as VLLW, LLW, ILW and in one case even as HLW waste and are intended for disposal both in surface and deep repositories.

Weaknesses: Both radiological and chemical characterization of these waste are lacking or poor; moreover in many cases the future treatment is not reported, probably due to the presence of toxic materials (treatment should be carefully assessed for streamlined disposability, taking into account normal and altered scenarios of the disposal solution and relevant man/environment impact thresholds).

Strenghts: Commonalities among countries of some waste streams in the group and small declared quantities suggest possible synergies in treatment routes (e.g. heat treatment for asbestos and PCB to eliminate intrinsic danger)

3.13 Liquid waste

Evidence: This group, common to 3 over 7 countries, includes liquid waste from various sources containing various radionuclides (beta, gamma and alpha emitters). They are packaged in different types of containers (glass bottles, plastic canisters overpacked in drums) and classified as LLW or ILW (in case of alpha bearing liquids) intended respectively for surface and deep disposal. Homogeneous conditioning is foreseen in two over three cases.

Weaknesses: Radiological characterization, where present, is of low reliability; chemical characterization is missing.

Strenghts: The homogeneity of the waste makes sampling and characterizing easier. The small declared quantities (few hundres of kg) suggest the possibility of shared solutions.

4 CONCLUSIONS

A survey has been performed among seven ERDO and non ERDO member countries, usually characterized by small inventories or early stage waste management programmes, aimed at investigating legacy waste streams generated to date and their main physical-chemical-radiological characterstics for enabling possible synergistic management activities up to shared disposal.

93 waste streams have been gathered in 13 homogeneous groups of streams, based on the main characteristic of the stream potentially impacting on the safety of future pre-disposal and disposal activities.

The survey and the relevant analysis revealed many similarities in the declared data of legacy waste streams and their envisaged future management.

In particular, 8 over 13 groups (Sealed radioactive sources, Solid mixed waste, Powdery waste, Sludges, Ion exchange resins, Graphite, Alpha bearing solid waste, Chemotoxic materials) are common to at least 4 out of 7 countries.

Except in one country and in the case of Sealed radioactive sources, the classificiation scheme is always defined but the lack or the low reliability of the radiological characterization (for more than 80% of the streams) make the classification quite uncertain. The planned characterization methodology for more than 40% of these streams has yet to be defined, while the remaining streams are planned to be characterized during the following sorting and treatment phases.

Notwithstanding such uncertainties, more than 50% of the waste streams are declared as ILW unsuitable for near-surface disposal (probably due to the expected concentration of long-lived radionuclides in the waste).

In a few cases the legacy waste streams have been conditioned according to obsolete rules and will require re-treatment and re-conditioning for complying with WAC when available; in all other cases the waste are simply packaged in raw (or pre-treated) conditions but the future treatment and conditioning activities are defined (mainly in the concept implementation phase) for less than 50% of the streams, the remaining declared as ‘not defined’ or ‘to be defined’.

The most important result of the survey is that many waste streams of 8 over 13 groups present strong similarities among countries and this, coupled with the small declared quantities of waste and the common needs of characterization and treatment/re-treatment for disposal, suggest possible synergies at least in pre-disposal management routes.

Additional chances of knowledge sharing or even pre-disposal facility sharing are linked to R&D European project (PREDIS[5]), innovative treatment processes on specific waste streams and the realization of a transportable in-drum grouting station declared by some countries.

The next ‘steps to sharing’ are therefore strongly connected to the implementation of bilateral-multilateral detailed info exchange and agreement among organizations managing similar waste streams with common pre-disposal needs.

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[5] https://predis-h2020.eu/