Radioactive Waste Retrieval Technologies - New technological approaches

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Abstract – *Final storages for radioactive waste are do not exist in all countries and because of that waste stored into provisional storages must from time to time be retrieved and reconditioned to be stored in new interim storages. For this purpose waste retrieval facilities are constructed, where the waste is sorted, waste volume reduced and filled into containers for a stable storage during the next 50 years. The paper describes the process of waste retrieval including presorting as the first step to recondition and to restore the waste in a new interim storage. Because of the high requirements for workers and environment safety new techniques are been developed to access the old waste storages and to handle the waste consolidation process. The integration of the waste retrieval into the waste control and surveillance architecture based on a tracking system is also described.*

I. INTRODUCTION

The solid waste retrieval facility (SWRF) is part of the solid waste management and storage facility (SWMSF) at Ignalina INPP, which is build to collect, classify and treat radioactive waste which has to be stored in the solid waste (interim) storage facility (SWSF) for about 50 years. This is necessary to have enough time to plan the final long term waste storage with a lifetime in the order of 500 or more years.

The purpose of the solid waste retrieval facility (SWRF) is to extract waste from its present storage location, pre-sort it, segregate adequate material for landfill disposal, and package non-landfill material for transportation to the solid waste treatment facility (SWTF).

II. DESCRIPTION OF THE WASTE

The waste which is stored in the paste into different buildings (155, 155/1, 157, 157/1) consist of:

- G1 waste: in general combustible (c) and non-combustible (nc) waste produced during normal operation and service function of INPP
- G2 waste: replaced equipment parts, components and maintenance service material
- G3 waste: generally metallic waste, produced in the hot cells or cutting facilities
- Special waste (which has to be sorted out): filters, asbestos, waste oil, PVC and spent sealed sources (SSS)

The radiological classification of waste should be:

- Class A: very low level waste for landfill
- Class B and C: low and intermediate level waste for short-lived (SL) intermediate storage
- Class D: low level graphite waste for long lived (LL) intermediate storage
- Class E: intermediate level waste for LL intermediate storage
- Class F: SSS waste for LL intermediate storage

To assign waste to the classes A-F, it is necessary to know the common radiological classification of solid waste as shown in Table 1.

Table 1

Common radiological characterization of solid waste

Waste Group	Surface dose rate[2]	Specific activity Bq/kg		Surface contamination Particles/cm^2 min	
	mSv/h	β-activity	α-activity	β-activity	α-activity
Low Level Waste (LLW)					
1	$1x10^{-4}$ – 0.3	$7.4x10^4$ - $3.7x10^6$	$7.4x10^3$ - $3.7x10^5$	$5x10^2$ - $1x10^4$	5 – $1x10^3$
Intermediate Level Waste (ILW)					
2	0.3 – 10	$3.7x10^6$ - $3.7x10^9$	$3.7x10^5$ - $3.7x10^8$	$1x10^4$ - $1x10^7$	$1x10^3$ - $1x10^6$
High Level Waste (HLW)					
3	> 10	> $3.7x10^9$	> $3.7x10^8$	> $1x10^7$	> $1x10^6$

In addition to the given definitions as shown in Table 1, the characterization as long lived (LL) and short lived (SL) are important, because this characterization influences

the time for which the waste must be stored until the radioactive isotopes are decayed to a harmless level.

SL means that the waste contains only isotopes with decay time less than 30 years including Cs-137. The limit activity value for long lived isotopes is <400Bq/g per waste package.

In all other cases the waste must be declared as LL.
It should be remarked, that the Table 1 gives criteria for the waste itself (specific activity [Bq/kg] and criteria for waste packages (surface contamination and surface dose rates).

During the retrieval activity only simple measurements like dose rate measurements can be performed. Therefore the simple waste classifications as G1, G2 or G3 waste is used. Later, in the SWTF, the precise characterization of the waste is performed after the treatment using monitors like the drum monitor system.

Before the waste is sent into the new interim storages, a new waste group classification is introduced as shown in Table 2.

Table 2

New radiological classification for SRW to be used as criteria for waste segregation in SWMSF

Waste Group	Definition	Surface dose rate	Conditioning	Disposal method
0	Exempt waste (EW)		Not required	Management and disposal type
Short-lived low and intermediate level waste				
A	Very low level waste (VLLW)	≤0.5 mSv/h	Not required	Very low level waste repository (Landfill Facility)
B	Low level waste (LLW-SL)	0.5-2 mSv/h	Required	Near surface repository
C	Intermediate level waste (ILW-SL)	>2 mSv/h	Required	Near surface repository
Long-lived low and intermediate level waste				
D	Low level waste (LLW-LL)	≤10 mSv/h	Required	Near surface repository (cavities at intermediate depth)
E	Intermediate level waste (ILW-LL)	>10 mSv/h	Required	Deep geological repository
Spent sealed sources				
F	(SSS)		Required	Near surface or deep geological repository

III THE SWRF

III.A. SWRF survey

The SWRF has to prepare the stored waste for treatment at the SWTF. Waste from future decommissioning is send later direct to the SWTF. After proceeding of the waste in the SWTF, the waste is stored in the intermediate waste storages for a period of about 50 years. After this period the waste has to be stored into final storages.

The SWRF mainly comprises three retrieval units and a control building. The retrieval units are cells within which the recovery, pre-sorting, segregation for Landfill, and packaging for transfer to SWTF take place. The control building is situated close to the existing storage buildings and is housing all common facilities including changing rooms, sanitary facilities and SWRF control room.

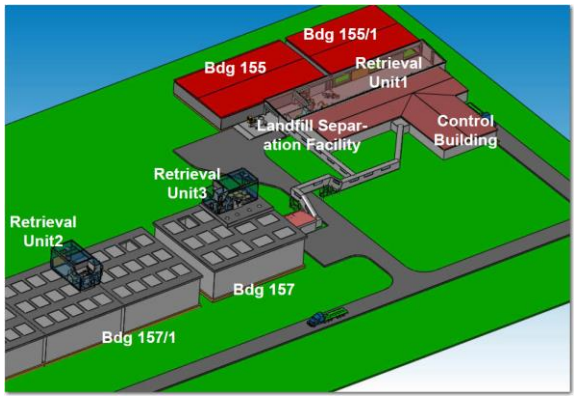

Figure 1: Survey of the SWRF and storage buildings

The advantage of using three retrieval units is that it will give operational flexibility.. It will be possible to modulate the output of each unit to suit the SWTF.

III.B. RETRIEVAL UNIT 1

Retrieval Unit 1 (RU1) will be used to retrieve waste from buildings 155 and 155/1. This is done using two remotely operated vehicles (ROV´s) which enter the storage compartments via access apertures cut in the side of the buildings by a diamond disk saw. The two ROVs will have complimentary capabilities, one providing a bucket scoop for collecting loose waste, the other a multifunction arm which can pick up large items such as bales or scaffold poles. The ROVs will be able to retrieve each other in the event of an equipment failure, allowing repair work to be undertaken in a suitably shielded area.

Containment will be provided via a “corridor” which will seal against the existing buildings. Ventilation systems

will maintain the operational area at a depression relative to the outside environment to minimize the risk of contamination escaping.

Waste sorting will be undertaken in RU1 pre-sorting area, allowing SSS, filter or other special waste to be identified, directly separated, and packed into transport container and send to the SWTF. Other G1 waste will enter the Landfill Separation Facility, which is attached to the RU1 building. In the Landfill Separation Facility the other G1 waste is pre-sorted and then sent, according to the requirements, to either Landfill Repository or SWTF.

The base of the sand pre-sorting skip will have a vibrating grid which will allow sand to fall into a catchment tray underneath where it will be collected by vacuum extraction and placed into “big-bags”. Bldg. 155 is expected to be dry.

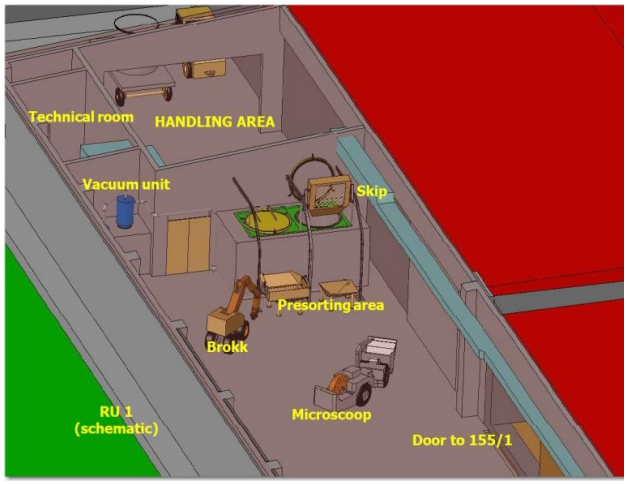

Figure 2: Equipment of RU1

Therefore, the sand present will also be dry, or possibly slightly moist, due to condensation.

The mesh need not be fine. In fact, it has to be rather coarse to allow pebbles passage. A reasonable size is around 30 to 40 mm. In these conditions, the effect of the pneumatic vibrator will allow the sand, even wet, to fall through this mesh.

The waste items dedicated for treatment in the SWTF will be loaded into one of two containers docked in special loading bays. The arrangement allows the external surfaces of the containers to remain contamination free during loading. After monitoring (and registering by the tracking system) the containers are moved to the SWTF under the authority of the main SWMSF control room.

G1 waste retrieved by RU2 when operating on G1 waste, enters through one of the two RU1 containers docking stations and is pre-sorted similar to G1 waste coming from buildings 155 and 155/1.

During, the G1 category A waste delivered from nuclear power plant enters the Landfill Separation Facility and is treated in respect to prepare Landfill.

Special attention is made for the radiological protection and survey. Most radiological protection in unit RU1 is provided by the design of the unit and remote control of the retrieval operations. Manned operations in normal conditions are reduced to handling operations for an average of 2 containers per day (around 10min).

In case of maintenance or abnormal operations that will require operators, individual protections are furnished. An additional movable shielding system can be placed to decrease the dose rate directly coming from the access door if necessary.

Intervention time and accumulated dose for the operators are monitored by the health physicist. The ambient dose rates in the work areas are monitored from the control room, and a decontamination campaign will be undertaken if it increases significantly.

The following fig. 3 shows the position of different means of radiation and contamination monitoring:

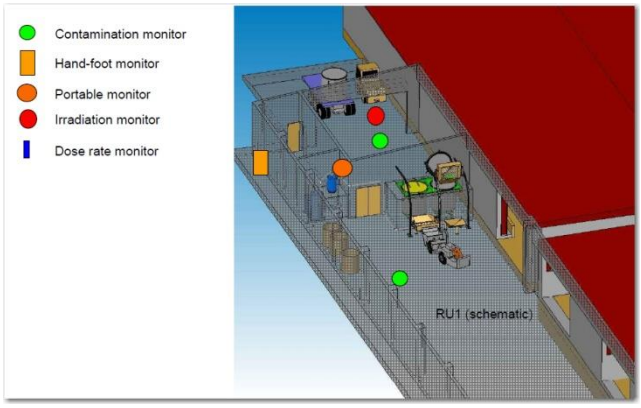

Figure 3: Radiation protection at RU1

III.C. RETRIEVAL UNIT 2

Retrieval Unit 2 (RU2) will be located at Building 157/1 and differs from RU1 in that it will be a mobile unit located on top of the building. The benefit of this

arrangement is that it is much safer than “tunneling” into the side of the much deeper piles of waste present in this building.

Initial retrieval will be undertaken by a dedicated crane and grab which will deposit the recovered items into a “pre-sorting” skip in a similar manner to RU1. Again a ROV will be used to segregate problematic items before the skip is emptied into the transport containers.

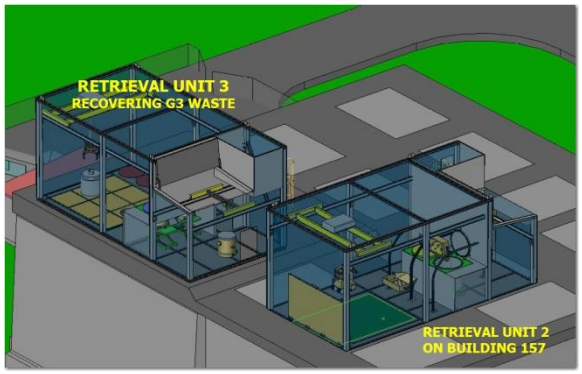

Figure 4: Retrieval Units 2 and 3

Once all accessible waste has been recovered by the crane, an ROV will be lowered into the compartment to load the remaining waste into a skip operated by the crane. Twin winches will be provided on the crane to allow redundancy and minimal risk of disruption. RU2 will be sealed to the top of Building 157/1 and a depression maintained by extracted ventilation.

III.D. RETRIEVAL UNIT 3

Retrieval Unit 3 (RU3) has two roles. During the first 5 years, it will be used to remove the G3 waste from Compartments 1 und 4, before removing the G1 and/or G2 wastes from Building 157. The method of retrieval for G1 and G2 waste will be similar to that used within RU2. Access to the compartments will be from the top of the building.

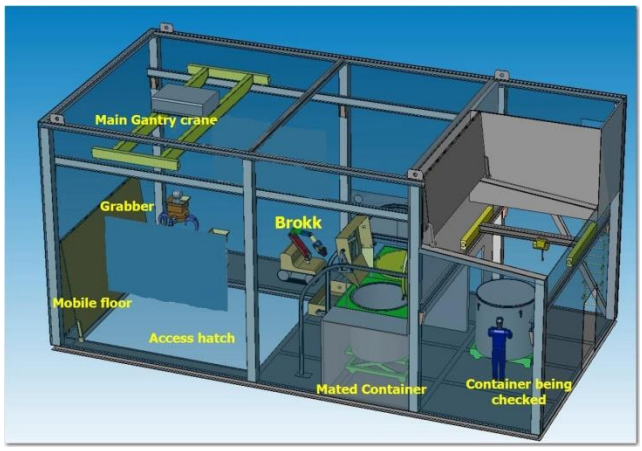

Figure 5: Retrieval Unit 3

G3 waste removal will need some changes to this procedure:

Firstly, the access holes will need to be enlarged to allow the ROV to be lowered into the compartments for final waste retrieval. It is essential that the cores cut in the floor do not fall into the compartments. The plug is removed and replaced with a bio-shield fitted with a inverted tripod system in its centre. This tripod can be actuated by means of rotating a threaded shaft. It expands to lock the concrete from below. It can be easily held in place. The peripheral holes are then cut. The coring tools are internally fitted with “one way dogs”, which allow the core to go in but prevent it from falling when it is cut. When all the peripheral holes are cut, the remaining part can be recovered.

Secondly, to avoid excessive radiation shine, a shielded bell arrangement around the grab is made to ensure radiation only shines downwards. Waste will be placed in G3 waste containers (without pre-sorting), for onward transport to the SWTF.

IV SPECIAL CONSIDERATION REGARDING THE TOP ACCESS OF STORAGE BUILDINGS

The top access to the buildings needs some precautions. The walls and the roof of the buildings must be stable enough to be used as foundation for the Removal Units. This approach is based both experience in similar projects and on the data available regarding the existing storage buildings. It is based on the following arguments:

1. When the Retrieval Unit is placed above one compartment, the lids have been removed.

2. The weight of one complete lid is approx. 25 tons. The overload due to the RU will therefore be limited to less than 15 tons, including the filled transfer containers.

3. While the lids apply their full load on the edges of the openings (which is the worst possible configuration with respect to stresses), the RU will apply its weight, by means of an adequately designed chassis, just above the compartment walls and partitions. Therefore all the stresses will be only compressive stresses, directly transmitted to the wall. This type of stress is well supported by concrete (assuming the weight is taken by 2 walls only, the overload on the partitions would represent less than 7N/cm2, to be compared with the compressive strength measure on the concrete samples during construction, of 2600 to 3800 N/cm2 (less than 0,3%).

4. Furthermore, the slab above each of the Compartments 1 and 4 of Building 157 having been loaded with an additional 70cm of concrete, weighing some 150 tons, we may safely assume that the extra 15 tons expected in the other areas will not be detrimental.
   The installation of RU3 will add around 35 tons on top of the thick slab. It can be expected that due to the thickness increase the slab will not be subject to unacceptable stresses. One problem may come from the walls, in case of seismic conditions. Therefore the building has to be assessed in respect to the building structure under seismic conditions. If this assessment will lead to unexpected requirements of structural support or reinforcement arrangements, such improvements must be accepted. Possible solutions in the present case for the Compartments 1 and 4 of Building 157 may be either a transfer of weight to the vertical walls, spreading the weight over a larger surface, or a transfer of weight directly to the ground, using an adapted armature.

Identified risks are limited as follows:

- For the Buildings 155 and 155/1: doors opening may weaken the walls. The solution is to brace the walls each side of the opening.
- For the Buildings 157 and 157/1: top slab does not support weight of units. The solution is to spread the weight over a larger surface, to transfer the weight to the vertical walls.

V. WASTE STREAMS OF THE SWRF

In the SWRF the waste is sorted into different waste streams. This will support the treatment as performed later in the SWTF. The main focus is put on the separation of special waste like PVC, Graphit etc. from the ordinary radioactive waste as replaced components, contaminated material etc.

The graphic below (fig. 10) gives an overview about the waste streams handled inside the SWRF and his destinations like SWTF, SWSF etc.

The sorting is performed according the radiological classification and the physical properties, important for volume reduction techniques. The majority of waste streams inside the SWRF are transmitted to the adequate waste streams of the SWTF for further treatment. At the end the waste should be conditioned for a safe and stable storage in the SWSF. This includes the separation between environment and waste and the stable storage inside of containments (i.e. no gazing, no corrosion or other chemical reactions etc.).

VI. WASTE INTERFACES

The most critical point in the retrieval units are the interface points where waste must be filled into containers, which are then transported out of the unit. The problem is to avoid contamination of the container surface to exclude the spreading of radioactivity by the container outside the retrieval unit (see Fig. 6).

Even if the containers are checked by wipe tests, there is no alternative to a careful design of the interface points, because any decontamination process is time and personal consuming.

Therefore the design must allow to fill the waste into the container without contaminating the containers surface by dust and aerosols. Also during the docking or undocking of the container any spreading of radioactivity must be excluded. In addition it has to be provided that all operations are performed remote operated.

VII. MAINTENANCE ROOM

During the retrieval of waste fork lifters, bale grabbers, skips etc. are operated to move the waste out of the storage buildings.

During the operation problems with the devices are possible. Because it can not be excluded that the devices itself are contaminated or that radioactive material may be in or fixed at part of the devices, a special area has to be provided for maintenance.

This area should be closed to the retrieval units for an easy access. The maintenance is to be performed using remote operated manipulators and radiation safe windows shown in Fig. 7.

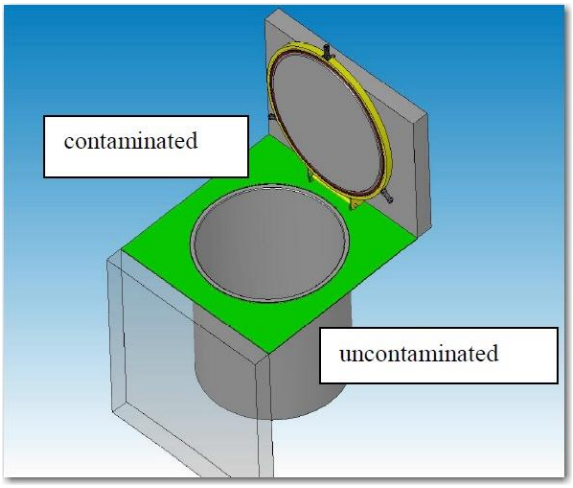

Figure 6: Design of waste interfaces

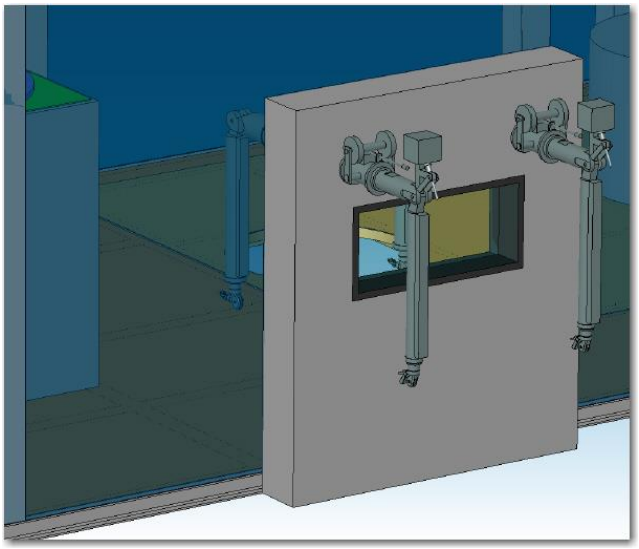

Figure 7: Maintenance room with remote operated manipulators

The retrieval operation will be managed from a central control building which will use state-of-the-art displays to provide the ROV pilots with excellent perception of the recovery area operations. The control room will also be connected with the SWTF to co-ordinate the dispatch and return of the waste containers and will have radio contact with the transport drivers, ensuring safe, efficient and controlled transfer operation.

To survey and control the different waste streams of the SWMSF and to document the treatment as well as the content of the SWSF, a tracking system (TS) is installed, which is connected with the different monitoring stations.

The TS is a central data base where all information about waste composition, radioactive classification, treatments, packages and place of deposition are stored. Because of the online and automated data tacking the TS is all time up-to-date.

All problems like device malfunctions, measurement parameters outside the specified limits etc. are directly send to the TS and are displayed at the control room either of the SWRF and/or the SWTF.

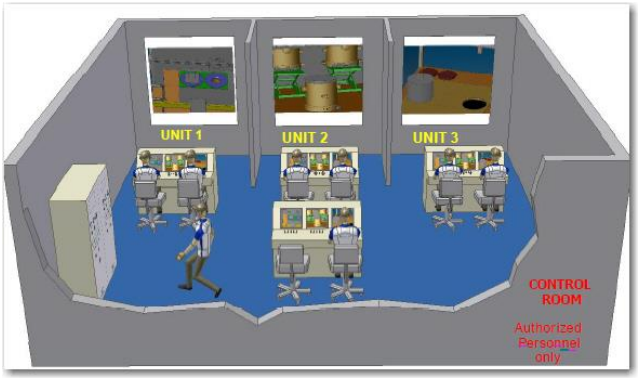

Figure 8: Control room of the SWRF

VIII. THE CONTROL ROOM

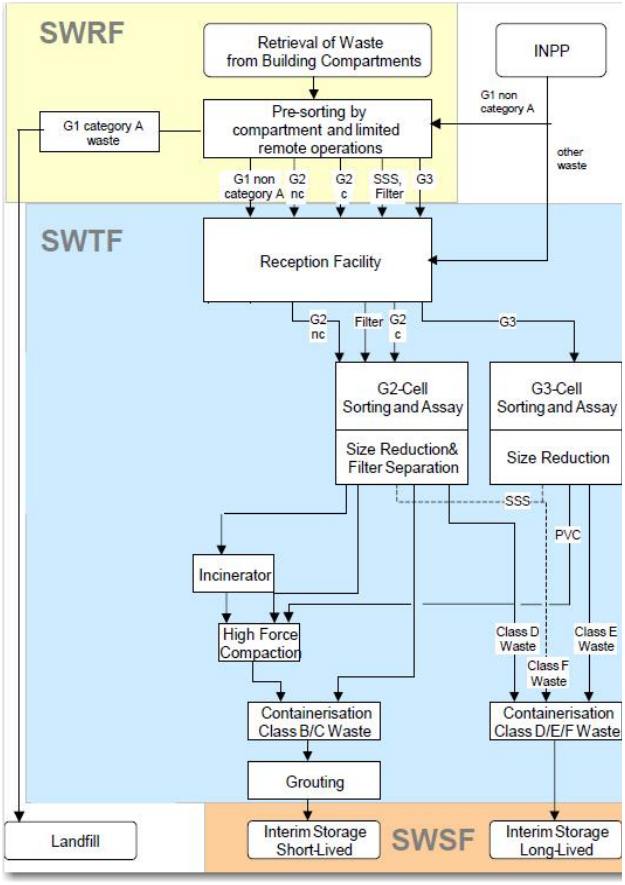

Figure 9: Waste streams inside the SWRF

IX. SECURITY SYSTEM

The security system includes 2 main functions:

- Access restriction and control
- Alarm monitoring and follow up

The access controlled perimeter of the SWRF has 2 access points:

- The door to the control building
- The gate allowing transfer vehicles to enter for loading/unloading containers, or other required vehicle access within the perimeter

The personal routes to the retrieval units are limited to a direct route starting from control building. Access to the Landfill Separation Facilitxy is directly from the control building. Access to the Retrieval Unit 1 is through the adjaced Landfill Separation Facility. Access to Retrieval Unit 2 and 3 will be provided by a stair case situated approximately midway along the length of the buildings 157 and 157/1.

In case of emergency, the shift supervisor in the control room will take the decision to evacuate the operators. The most appropriate meeting point, because of its central situation, is next to the vehicle gate.

RU1 operators will take the same route as used for access to the RU. Evacuation time from RU1 to the control room is estimated to be about 1 minute.
In RU2 and RU3, evacuation time is estimated at about 2 minutes, taking into account the time needed to climb down stairs and the numerous possible configurations of the units.

The shift supervisor in control room has to take decision and order the operator either to stay in the shelters or take the whole escape route to the control room.

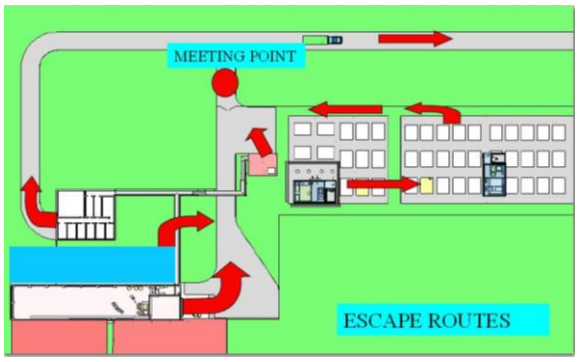

Figure 10: Escape routes

X. CONCLUSIONS

Retrieval facilities are needed to condition the radioactive waste stored or simply dumped into buildings or underground vaults for the next interim or final storage period. This requires special techniques for a safe and efficient waste handling.

In the past the focus was put on methods for volume reduction and separation of waste with different activity classes.

Nowadays techniques for a safe access to the existing storages are developed in respect to strengthened safety provisions for workers and environment. This includes the design of the access to the waste storages but also the procedures to transport safely the waste to other locations like treatment facilities etc.

New is also the increased demand for survey of the waste streams during the operations and the documentation of the quality of work in respect to the efficiency but also to the safety for workers and environment. For this purpose a tracking system was designed to be able to give all times snapshots about the waste streams and waste places.

Last but not least there are strengthened requirements for the characterization of the restored waste in respect to the possible future final deposition for long time like in deep geological depositories.

NOMENCLATURE

SWMSF: solid waste management and storage facility
SWRT: solid waste retrieval facility
SWTF: solid waste treatment facility
SWSF: solid waste storage facility
ROV: remote operated vehicle
INPP: Ignalina nuclear power plant
SSS: spent sealed sources
RU: retrieval unit
LSF: landfill separation facility