# ROUTES SUBTASK 2.2

## Bituminization of evaporated concentrate at the Rivne NPP in Ukraine: An example of conditioning waste without disposal WAC being available

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## *BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)*
## PART 1: CONTEXT

- **Brief description of the involved waste:**
  - Origin: bituminization of evaporated concentrate at Rivne NPP
  - Location: Rivne NPP (current storage location)
  - Classification: LLW (IAEA classification i.e. destined for near surface disposal)
  - Quantity: ±150 $m^3$ bituminized waste in metal drums
  - Main characteristics: evaporated concentrate in bitumen matrix, main nuclides include Co-60, Sr-90, Cs-134 Cs-137;
  - Task 2 challenging waste category: bituminized waste
  - Challenging waste
    - Main reason: Conditioned without WAC for disposal available
    - Main concerns: (1) fire and possible explosion hazard, (2) uncertain homogeneity of bituminized waste
    - Task 2 challenging waste category: bituminized waste
- **Anticipated final destination for this waste:** Vector complex (near-surface disposal)

## *BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)*
## PART 2: DESCRIPTION OF CASE STUDY

### Applicable waste management steps

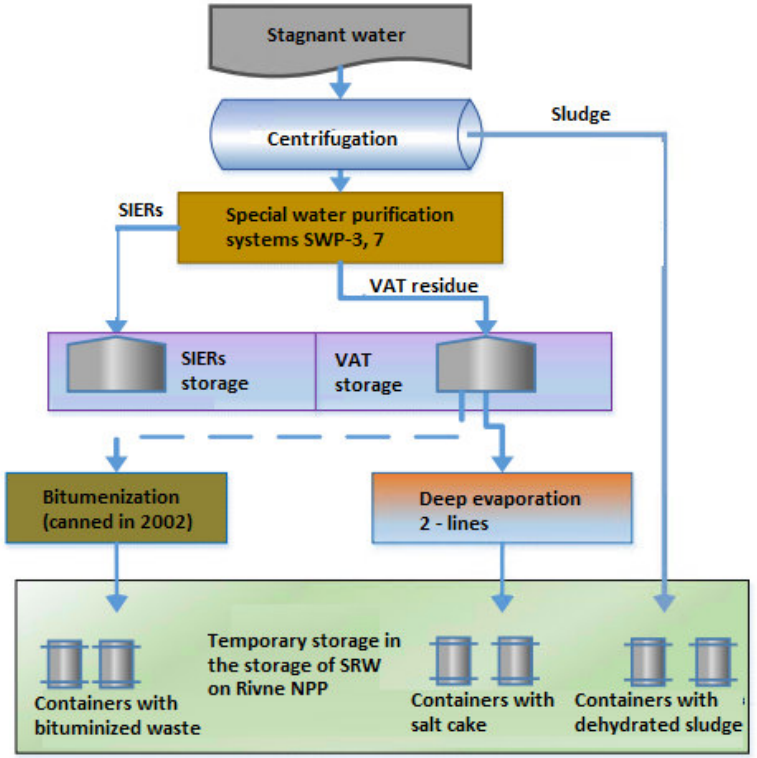
- Radiation, chemical and physical characterization of bituminized waste (methodologies for characterization, performance characterization)
- Transportation of bituminized waste
- Additional immobilization of bituminized waste in reinforced concrete containers
- Assessment of bituminized waste disposal safety
- Disposal of immobilized bituminized waste on Vector site

## *BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)*
## PART 2: DESCRIPTION OF CASE STUDY

- **Key uncertainties at the time**
  - Radionuclides inventory list of bituminized waste
  - Chemical and physical characteristics of bituminized waste
  - WAC for next radioactive waste management step including disposal

- **Example of conditioning non bituminized waste without WAC for disposal:**
  - Re-evaporation of evaporated concentrate at operating NPPs with the production of salt cake in metal containers
  - Dehydrated sludges obtained at the centrifugation installation and placed into steel drums at Rivne and Khmelnitsky NPPs

*General scheme of liquid RW management at RNPP*

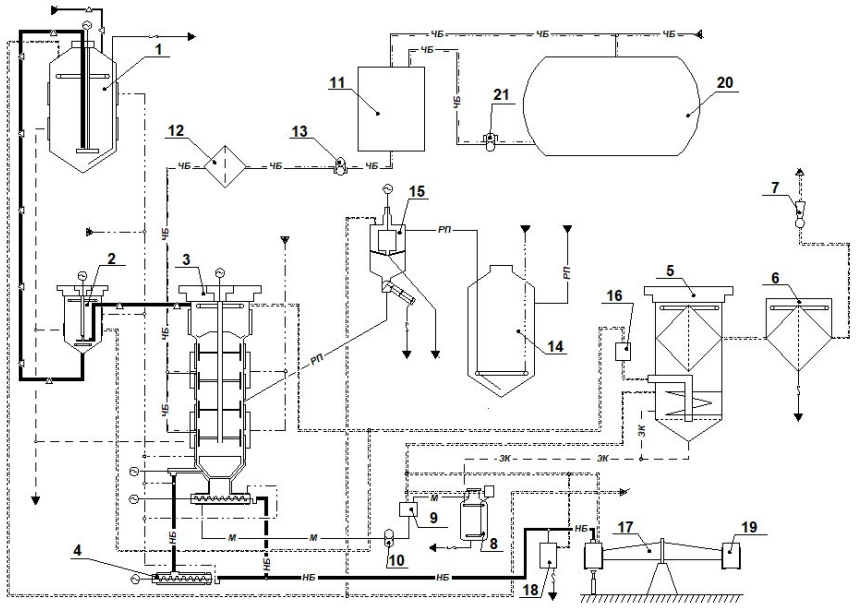


## *BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)*
## PART 2: DESCRIPTION OF CASE STUDY

*Main technical characteristics of bituminized process*

| Name parameter | Value |
|---|---|
| VAT residue consumption | 80-160 l/h |
| Bitumen consumption | 40-120 l/h |
| Concentration of salts in the VAT residue | 100-400 g/l |
| Compound properties (project) | |
| Filling with RW | 40-60% |
| Humidity | 1-5 % |

*Scheme of RW bituminization process, SAR*

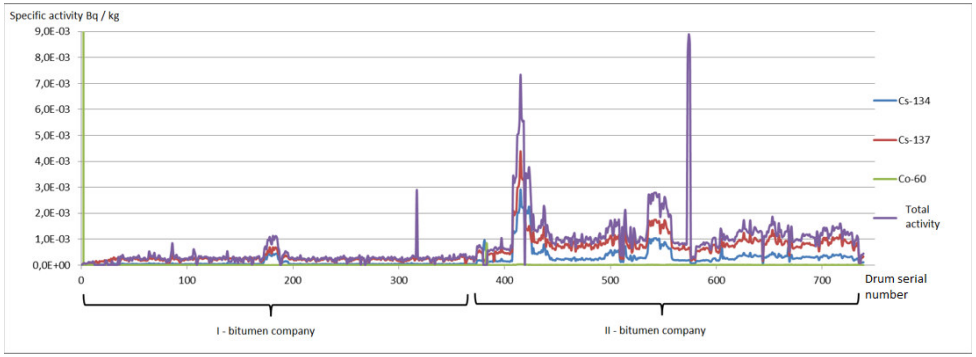


## *BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)*
## PART 2: DESCRIPTION OF CASE STUDY

### Origins

- Packages bituminized waste (final product of evaporated concentrate processing) were produced during the processing of liquid RW at the Rivne NPP in the period 1995-1996 and 2001-2002.
- Total was produced 739 drums with bituminized waste
  - 373 drums in period of 1995-1996
  - 366 drums in period of 2001-2002

*Primary radiation characterization of* bituminized waste

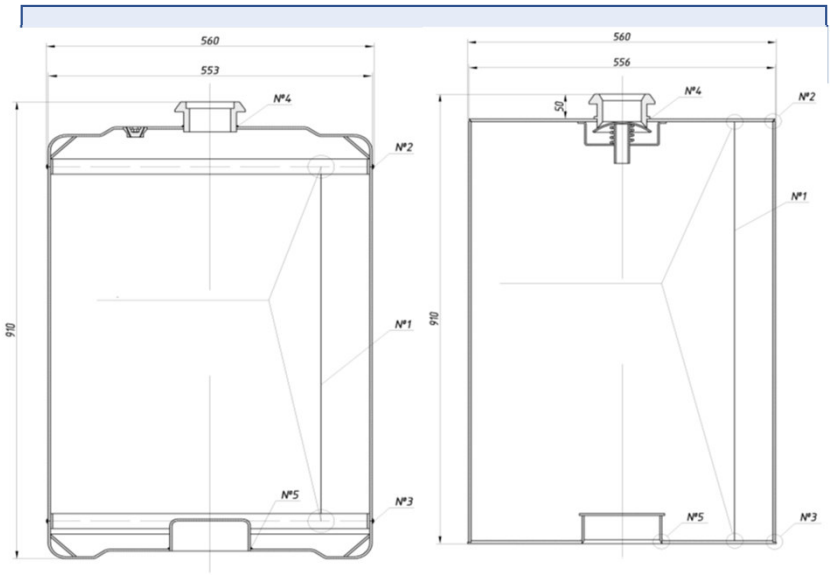


## *BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)*
## PART 2: DESCRIPTION OF CASE STUDY

- **Bituminized waste is stored in the storage for solid radioactive waste on Rivne NPP in containers with a capacity 0,2 m$^3$ of two types:**
  - A 2201.00.000
  - ZP 551.040.00.000
- **External anti-corrosion coating - silicon-organic composition OS-51-03**
- **The only manipulation hole on the surface of the containers is a neck with diameter of 50 mm.**

| Container brand | Steel thickness, mm | Steel grade |
|---|---|---|
| A 2201.00.000 | 3,9 | St 3 |
| ZP 551.040.00.000 | 3,9 | St 20 |

*Bituminized waste packages*




A 2201.00.000 ZP 551.040.00.000

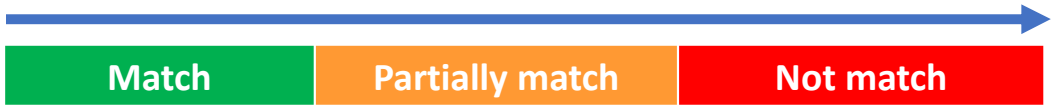
***BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)***

## PART 2: DESCRIPTION OF CASE STUDY

List of the waste acceptance criteria for ENSDF

| Radiological | Chemical | | Physical |
|---|---|---|---|
| **Radionuclide inventory list and activity** | Chemical composition | **Complexing and chelating reagents** | Permeability and porosity |
| **Max activity values** | **Toxicity** | **Fire resistance** | Structural stability |
| Radiation resistance | **Free liquid** | **Gassing** | Cavities |
| ***Homogeneity*** | **Explosiveness** | Corrosion resistance of RW packages | Mechanical strength of RW packages |
| Critical safety | Compatibility | Biological stability | Heat |
| Dose rate | Leaching | | Thermal stability |

**WAC for ENSDF were established at 2008, and the lust drum with bituminized waste was produced at 2002**



***BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)***

## PART 2: DESCRIPTION OF CASE STUDY

### Characterization of bituminized waste

**Steps of characterization for bituminized waste:**

- **Collection and analysis of existing information and determination of parameters and required volumes of characterization**
- **Development and approval with the regulatory body of characterization methodology, including:**
  - Methodology of sampling
  - Methodology of radiation, chemical and physical characterization

  The main norm documents which used for determining of the characterization parameters and measurement methods are:
  - Recommendations for establishing waste acceptance criteria for conditioned radioactive waste in near-surface disposal facilities (RD 306.4.098-2004)
  - Guideline to the characterization, accounting and control of radioactive waste (developed in scope of INSC PROJECT U3.01/10 (UK/TS/46))
- **Analysis of the obtained results and additional research (free liquid, chelating, leaching, cavities, explosiveness)**

*BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)*

## PART 2: DESCRIPTION OF CASE STUDY

### Characterization of bituminized waste

**Some documents used to determine the preliminary characteristics of bituminized waste**

- **Safety analysis report bituminization installation**
- **Conclusion on the explosion safety of the process of evaporation of the vat residue and obtaining bitumen compounds, 1990**
- **Study of the properties of solidified waste in order to ensure the safety of their storage, 1990**
- **Technical conditions for the container TU 95-2424-93**

***BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)***

## PART 2: DESCRIPTION OF CASE STUDY

### Characterization of bituminized waste

### Methodology of sampling

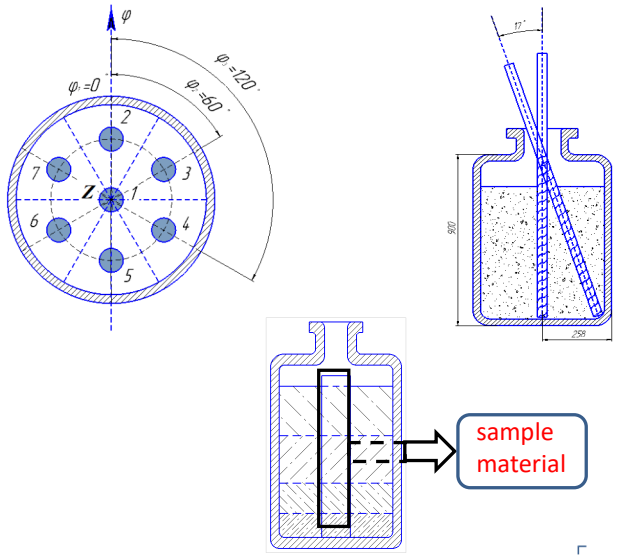
**Sampling:**

- 10 samples from the packages with the maximum Cs-137 activity (2 samples per 1 drum)
- 15 samples from each batches which are produced in different period (1 samples per 1 drum), drums in each batches were selected randomly

In total, 40 samples were used to characterize bituminized waste.

**Sampling bituminized waste was performed by drilling through the hole in the neck of the drums.**

*Schematic representation of sampling points within a single container*



## *BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)*

## PART 2: DESCRIPTION OF CASE STUDY

### Characterization of bituminized waste

### Radiological characterization

**During the radiological characterization, the nuclide activities were determined and the scaling factors of the nuclide vector were calculated.**

**The following approaches were used to determine the scaling factors:**

a) **isotope Cs-137 was chosen as a reference radionuclide for calculation of specific activity of Sr-90 and Cs-134**

b) **to determine the specific activity of radionuclides (H-3, C-14, Ni-63, Tc-99, U-235, U-238, Pu-238, Pu-239, Pu-240, Am-241, Th-232) was used a conservative approach which based on max activities of each**

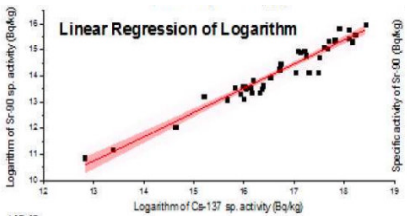
c) **to determine the specific activity of radionuclides with activity values lower than the minimum detected (Be-10, Cl-36, Ca-41, Mn-41, Fe-55, Ni-59, Zr-93, Nb-94, Ag-110m, I-129, Cs-135, Ra-226, U-236, Np-237, Pu-241, Pu-242, Am-243) was used a conservative approach which based on resolution of the measurement method**

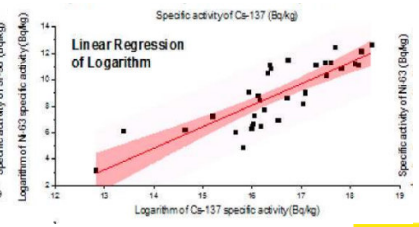
**The activity of cesium Cs-137 changed in rate $3{,}68*10^5 \div 1{,}00*10^8$ Bq/kg**

**Dose rate and surface contamination for the container were determined**

*List of radionuclides that were characterized*

| | | | |
|---|---|---|---|
| $^{90}Sr$ | $^{238}Pu$ | $^{243}Am$ | $^{226}Ra$ |
| $^{134}Cs$ | $^{239+240}Pu$ | $^{36}Cl$ | $^{54}Mn$ |
| $^{99}Tc$ | $^{241}Am$ | $^{41}Ca$ | $^{94}Nb$ |
| $^{63}Ni$ | $^{235}U$ | $^{55}Fe$ | $^{110m}Ag$ |
| $^{14}C$ | $^{3}H$ | $^{93}Zr$ | $^{59}Ni$ |
| $^{232}Th$ | $^{236}U$ | $^{129}I$ | $^{10}Be$ |
| $^{238}U$ | $^{242}Pu$ | $^{241}Pu$ | $^{135}Cs$ |



***BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)***

## PART 2: DESCRIPTION OF CASE STUDY

Characterization of bituminized waste

Chemical characterization

- During the chemical characterization the chemical composition was determined (concentration of different ions, including salts bases, etc.).
- Some characteristics of the waste (gassing, toxicity etc.) are determined based on its chemical composition
- Free liquid was found in 5 containers

**Main chemical characteristics**

| Parameter | Value |
|---|---|
| pH | 9,74 — 10,92 |
| Humidity, % | 0,4 — 27,7 |
| Maximum leaching speed, g/ (cm * day) | $3{,}02*10^{-6}$ — $6{,}19*10^{-3}$ |
| Degree of filling salts, % | 2,49 — 71,86 |
| $NO_3^-$, g/kg | $5{,}81\cdot10^{-3}$ — $2{,}84\cdot10^{2}$ |
| $Na^+$, g/kg | 3,50 — 174,4 |
| EDTA, mg/kg | 364 — 395 |

***BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)***

## PART 2: DESCRIPTION OF CASE STUDY

### Characterization of bituminized waste

Chemical characterization

Studies were performed to show the safety of the each management steps of RW including disposal. WAC for near-surface disposal at Vector complex can be revised taking into account the results of bituminized waste characterization.

The results of these studies are favorable with respect to:

- compatibility of the bituminized waste with the metal drums and their corrosion resistance
- absence of substances that react with water with heat release and generation of combustible and explosive gases
- toxic substances

The safety case is further supported by 20-27 years of experience with safe storage of this bituminized waste at the Rivne NPP.

## *BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)*

## PART 2: DESCRIPTION OF CASE STUDY

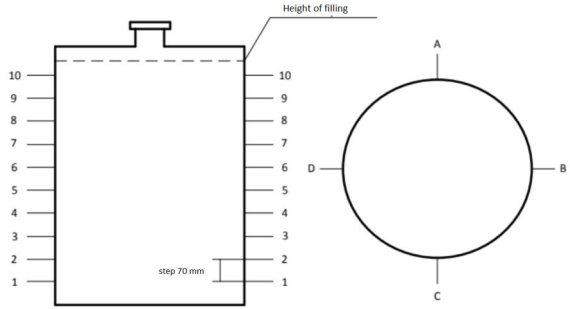
### Characterization of bituminized waste

### Physical characterization

During the physical characterization was determined homogeneity of bituminized waste, cavities, structural stability of containers (based on drums wall thickness).

| Parameter | Value |
|---|---|
| Homogeneity | < 1.8 times from average |
| Cavities | up to 70% |
| Drums wall thickness, mm | > 3,5 mm |

*The scheme of measuring the homogeneity*



***BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)***

## PART 2: DESCRIPTION OF CASE STUDY

Characterization of bituminized waste

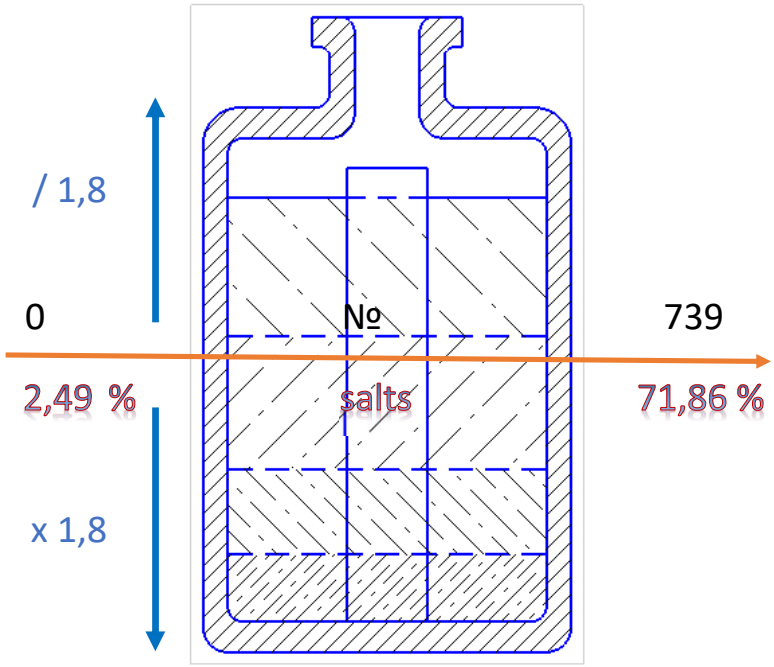
### Explosiveness

According to «Conclusion on the explosion safety of the process of evaporation of the vat residue and obtaining bitumen compounds, 1990» bituminized waste produced at the on Rivne NPP installation can be explosive at concentration of $NaNO_3$ in them more then 60% of mass (VNIINM, O.L. Maslanov, L.A. Mamaev).

When analyzing of the explosion safety, it is should be taking into account both:

- inhomogeneity of the each drums
- uneven distribution of salts along the height of the drums

It is planned to provide additional investigation of explosiveness



## *BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)*
## PART 2: DESCRIPTION OF CASE STUDY

**Assessment of bituminized waste disposal safety**

- **Now, it is envisaged to transfer this radioactive waste to the Vector complex for disposal in engineering near surface disposal facilities (ENSDF)**
- **ENSDF under operation from 2008, consists of 22 modules for disposal of low- and intermediate-level short-lived solid RW with total volume 55000 м$^3$**
- **For bituminized waste disposal must be provided additional safety assessments and treatment**

**ENSDF outside look**

***BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)***

**PART 2: DESCRIPTION OF CASE STUDY**

Disposal of bituminized waste

## Immobilization

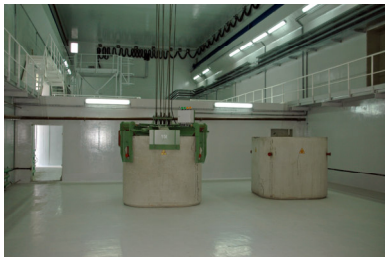
Bituminized waste immobilization will be carried out at the Chernobyl NPP on Industrial Complex for Solid Radioactive Waste Management (ICSRM).

Bituminized waste planned to be placed in a reinforced concrete container KTZ-3.0, 5 barrels in each and filled with concrete.

Before placing the drums with bituminized waste in container KTZ-3.0, it is planned to characterize them using approved nuclide vector.

It is also planned at the ICSRM to fill with concrete the existing cavities in the drums as much as possible

ICSRM



***BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)***

## PART 2: DESCRIPTION OF CASE STUDY

Characterization of bituminized waste

### Immobilization, KTZ-3.0 characteristics

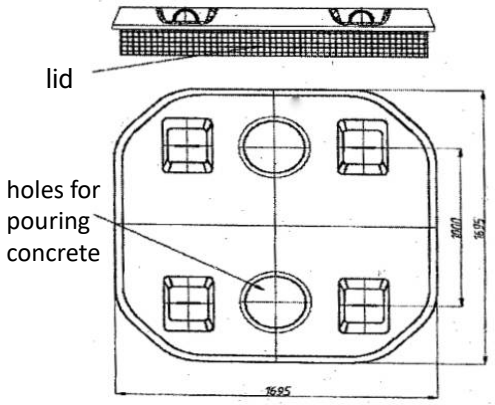
KTZ-3.0 is made with heavy concrete:

- compressive strength – class B30
- frost resistance – class F100,
- damp penetration – class W6

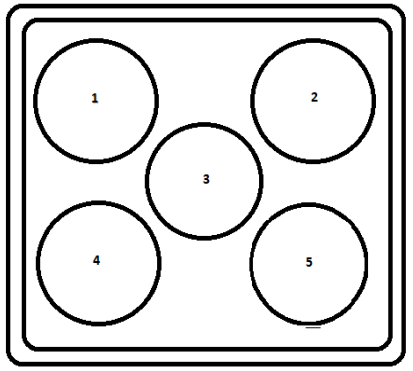
Physical dimensions

| | |
|---|---|
| Length | 1940 mm |
| Width | 1940 mm |
| Height | 1650 mm |
| Mass, empty | 5470 kg |
| Max mass with waste | 14100kg |
| Wall thickness | 150 mm |

**KTZ-3.0**




**Drums in KTZ-3.0**



*BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)*

## PART 2: DESCRIPTION OF CASE STUDY

Disposal strategy for bituminized waste

### Disposal, compliance with WAC

Additional assessments are required to confirm the safety of disposal such a volume of bituminized waste

**A significant degree of conservatism has been used in approaches to the development of ENSDF WAC, some criteria may be revised and "weakened"**

**Total volume of waste is approximately 150 $m^3$, which is approximately 0,3% of the ENSDF total volume, and will accordingly have the same effect on disposal safety**

### Compliance with ENSDF WAC

| WAC | Waste | ENSDF |
|---|---|---|
| Free liquid | free liquid is present Humidity up to 30 % | not allowed |
| Homogeneity | up to 1.8 times the average | up to 2 times the average |
| Complexing and chelating reagents | EDTA, 364 ÷ 395 mg/kg | not allowed |
| Cavities | up to 70% from drum volume | as low as possible |
| Toxicity | some chemical elements are present | not allowed |
| Explosiveness | explore | confirmed for some barrels |

***BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)***

## PART 2: DESCRIPTION OF CASE STUDY

Disposal of bituminized waste

### Disposal

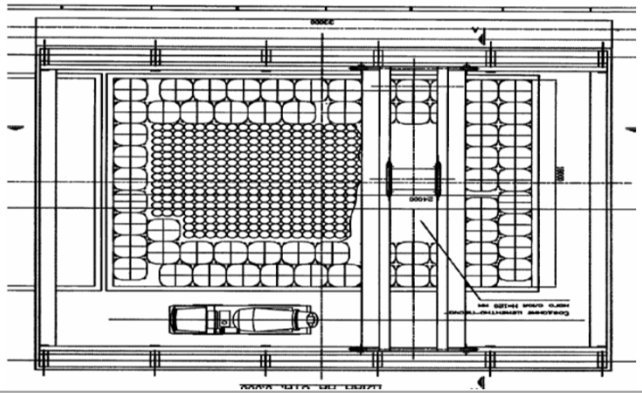
ENSDF under exploitation from 2008, consists of 22 modules for disposal of low- and intermediate-level short-lived solid RW with total volume 55000 $m^3$

Today the first two ENSDF modules are being filled and 150 $m^3$ of bituminized waste will take 3% of volume at these modules

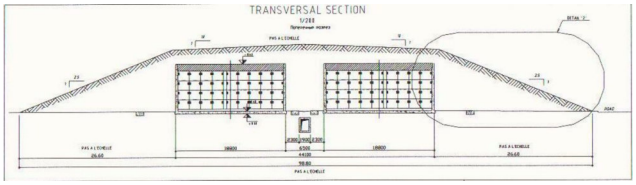
In ENSDF accepted for disposal:

- reinforced concrete containers with cemented RW from ICSRM
- 200 l drums with cemented by special technology liquid RW from the Liquid Radioactive Waste Treatment Plant (LRTP)

*Layout of RW packages in disposal facility*



*Final disposal*



***BITUMINIZED WASTE OF RIVNE NPP (UKRAINE)***

## PART 3: EVALUATION & LESSONS LEARNED

### Conclusions

- The disposal strategy for the bituminized waste have been chosen
- Radiation, chemical and physical characterization of bituminized waste was performed (additional explosion hazard study is required)
- Safety assessments of waste immobilization at the Chernobyl NPP and disposal of immobilized waste at the Vector site are performed

Experience taken from case study

- RW management activities should be well considered at each step until their disposal
- A quality system for waste management must be ensured, in particular, waste processing technologies needed to be followed.

# THANK YOU VERY MUCH FOR YOUR ATTENTION !