Removal of Dust Suppressor and TRU Elements from Wastewaters of Chernobyl NPP Using Synthetic and Natural Flocculants

Abstract #12374

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IAEA expert missions at ChNPP during 2009-2012 to develop principal technology and pilot test unit to remove organic contaminants and TRU from “Shelter” Object wastewaters

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Dust Suppressor Emulsion Application at ChNPP

- Sprayed dust suppressor solution and waters after washing spraying system are not separated.
- Non-dried dust suppressor emulsion penetrates down the “Shelter” (Unit 4) rooms to bottom levels and into the adjacent Unit 3 through concrete wall.
ChNPP 3rd and 4th Unit LRW Accumulation Flow Sheet

«Shelter» Object

Drainage system of the 3rd Unit

SVO-4

LRW and SRW storage

LRW storage
Dust suppressor containing LRW

3rd and 4th Unit drainage waters

- **Salinity:** <1 g/L
- **Total α-activity:** 1-2 E+04 Bq/kg
- **Total β-activity:** 0.9-4.0E+06 Bq/kg
- **Dust suppressor content:** 0.1-2 g/L

![Graph showing volume of drainage waters from 2000 to 2011.]

Evaporator concentrates of 3rd and 4th Units drainage waters

- **Salinity:** 300-500 g/L
- **Total α-activity:** 3-4 E+03 Bq/kg
- **Total β-activity:** 3-4 E+07 Bq/kg
- **Dust suppressor content:** ~0.3-0.5 g/L

![Image of evaporator concentrate.]

Volume at LRW storage:

13 500 m³
Construction of LRW Treatment Plant is currently suspended

• Designing is 99% completed
• Construction is 98% completed
• Mounting is 97% completed

Problems identified

• Accumulated wastes contain high amounts of dust suppressor and **CANNOT** be treated by evaporation-cementation set up in a new facility.
• TRU content in LRW must be reduced prior to cementation.
Polymerization of dust suppressor under elevated temperature results in formation of virtually insoluble rubber-like deposits on heat-exchangers of the secondary evaporator of SVO-4.

Rubber-like precipitates are formed at $T > 130^\circ$C (salinity $> 150$ g/L)
Formation of rubber like precipitates in sealed system of a new LRW Treatment Plant will damage heat exchangers and block facility operation.

Possible approaches to remove dust suppressor from LRW:

- Oxidation (ozone, peroxides)
- Sorption (active carbon)
- Filtration through ion-exchangers
- Flocculation with cationic polyelectrolytes
Removal of Dust-Suppressor

by peroxide oxidation

Only up to 10% of dust suppressor can be removed

Required DF > 200
Flocculation/sedimentation setup for dust suppressor and TRU removal

Charge neutralization of TRU colloids, pH>8

Dust suppressor removal
## Composition of LRW used in the Pilot tests

<table>
<thead>
<tr>
<th></th>
<th>pH Dry residue, g/L</th>
<th>([\text{C}_2\text{O}_4]) Oxygen consumption, mg/L</th>
<th>Total (\alpha)-activity, Bq/kg</th>
<th>Specific activity, Bq/kg</th>
<th>(D^{500}) DS, mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BTV</strong></td>
<td>9.45</td>
<td>13.50</td>
<td>1.66E+04</td>
<td>60(^{53})Co: 3.53E+04</td>
<td>1.825</td>
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<td></td>
<td>1.10</td>
<td>220</td>
<td>9.49E+05</td>
<td>134(^{77})Cs: 7.77E+02</td>
<td>233</td>
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<td></td>
<td></td>
<td></td>
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<td>137(^{54})Cs: 7.54E+05</td>
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<td></td>
<td>154(^{21})Eu: 2.51E+03</td>
<td></td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>155(^{18})Eu: 1.82E+02</td>
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<td></td>
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<td></td>
<td></td>
<td>241(^{23})Am: 1.30E+04</td>
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<tr>
<td><strong>0005</strong></td>
<td>9.71</td>
<td>22.5</td>
<td>1.30E+04</td>
<td>60(^{53})Co: 8.92E+02</td>
<td>2.500</td>
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<tr>
<td></td>
<td>0.8</td>
<td>600</td>
<td>3.62E+06</td>
<td>134(^{77})Cs: 6.94E+02</td>
<td>327</td>
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<td>137(^{54})Cs: 2.37E+06</td>
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<td>154(^{21})Eu: 1.80E+03</td>
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<td>241(^{23})Am: 1.02E+04</td>
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<tr>
<td><strong>201/3</strong></td>
<td>11.42</td>
<td>8730</td>
<td>4.41E+03</td>
<td>60(^{53})Co: 8.22E+03</td>
<td>0.566</td>
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<tr>
<td></td>
<td>(evaporator concentrate)</td>
<td></td>
<td></td>
<td>134(^{77})Cs: 3.77E+04</td>
<td>(D(^{1000})) 150</td>
</tr>
<tr>
<td></td>
<td>275.4</td>
<td>5000</td>
<td>3.18E+07</td>
<td>137(^{54})Cs: 2.63E+07</td>
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<td>241(^{23})Am: 3.46E+03</td>
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</table>
Pilot Unit at Chernobyl NPP

General view of the pilot unit:

service tank (1), precipitation tank (2), accumulation tank (3), membrane pumps for reagents feeding (4), reagent vessels (5), mechanical filters (6), heat-exchanger (7), circulating pumps (8).
Coagulant/flocculant dose optimization: drainage waters

Residual DS concentration in drainage waters of “Shelter” unit after flocculation

Mechanical filtration of treated LRW

Comparison of chitosan and synthetic flocculants BesFloc (Republic of Korea)

Synthetic flocculants form gel-like precipitates and are not applicable in flocculation-filtration set-up
Sedimentation/Filtration Stage

- Sedimentation time (flocs ripening) – 5-10 min: continuous process is possible

- Mechanical filtration rate is 10 to 120 L/h (filters – 2 dm³ each)

Filtration media tested:
sand, ion-exchangers «Dowex Monosphere» - cation-exchanger (650NG) and anion-exchanger (550NG) mixed at ratio 1:1.5 to simulate spent ion-exchange resins available at ChNPP
Coagulant/flocculant dose optimization: evaporator concentrates

Reagents tested

- PACS
- chitosan
- BesFloc cationic flocculants
- addition of calcium salts to suppress oxalate effect

Decontamination factor for DS is 5-10

Due to the lack of electrostatic interactions in high salinity media (>200 g/L) flocculation/sedimentation set-up is not efficient for evaporator concentrates
### Selected Pilot Test Results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Reagent dose</th>
<th>D$_{500}^5$ (filtrate)</th>
<th>Total $\beta$-activity, Bq/kg</th>
<th>Total $\alpha$-activity Bq/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment №1</strong>&lt;br&gt;<strong>BTV</strong></td>
<td>POLYPACS 200 mg/L Chitofloc 7.8 mg/L</td>
<td>0.053 5.51</td>
<td>6.11E+5</td>
<td>n/detected</td>
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<tr>
<td><strong>Experiment №2</strong>&lt;br&gt;<strong>BTV</strong></td>
<td>POLYPACS 125 mg/L</td>
<td>0.015 0.64</td>
<td>7.05E+5</td>
<td>n/detected</td>
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<tr>
<td><strong>Experiment №3</strong>&lt;br&gt;<strong>0005</strong></td>
<td>POLYPACS 260 mg/L Chitofloc 10 mg/L</td>
<td>0.029 2.43</td>
<td>1.77 e+6</td>
<td>n/detected</td>
</tr>
</tbody>
</table>

Decontamination factors for drainage waters: DS>500, TUE>1000
How to treat 13 500 m³ of dust suppressor containing evaporator concentrate?

Possible solution: polymerization of DS under hydrothermal conditions before evaporation

Main subunits of the hydrothermal unit
1 – feeding tank
2, 5 – pumps
3 – sorption filter for cesium removal
4 – tank for treated wastes collection
6 – hydrothermal reactor
7 – oven
8 – thermocouple
12 – cooler
Hydrothermal Unit of the Pilot Unit at ChNPP

Treatment conditions

\[ T = 270-310^\circ \text{C} \]
\[ P = 80-100 \text{ bar} \]

evaporator concentrate before treatment
PROSPECTS

Drainage waters

Evaporator concentrates

2012

Development of Technical Specification for Pre-Treatment Facility

Decision to be made

Cementation without deep evaporation at new facility

2013 -

Design and Construction of Pre-Treatment Facility

Development of Technical Specification for Pre-Treatment Facility