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# **Scenarios of Radiological Impacts in the Long-term Safety Analysis of Radioactive Waste Disposal at the Vector Site Located in the Chernobyl Exclusion Zone**

# National RW Management Strategy

- **Radioactive Waste Management Strategy in Ukraine** approved by the Order of Government № 990, 19 August 2009
- **State National Ecological Program of Radioactive Waste Management** approved by Law of Ukraine № 516-VI, 17 September 2008
- **Feasibility Study of II Stage of Vector complex** approved by the Order of Government № 1605, 23 December 2009

# National RW Management Strategy

- Processing and conditioning RW on the sites where they were produced (NPP)
- **Centralized processing of RW at the facilities at Vector site** for small producers (medicine, research, industry)
- **Centralized long-term storage and disposal of conditioned RW at the disposal facilities at the Vector site in Exclusion Zone**
  - disposal of low-level short lived RW in near-surface facilities
  - long-term storage of long-lived and high-level RW

# Vector site in Exclusion Zone - National Centre for disposal, storage and processing, and of all types of RW from Ukraine

## Will include

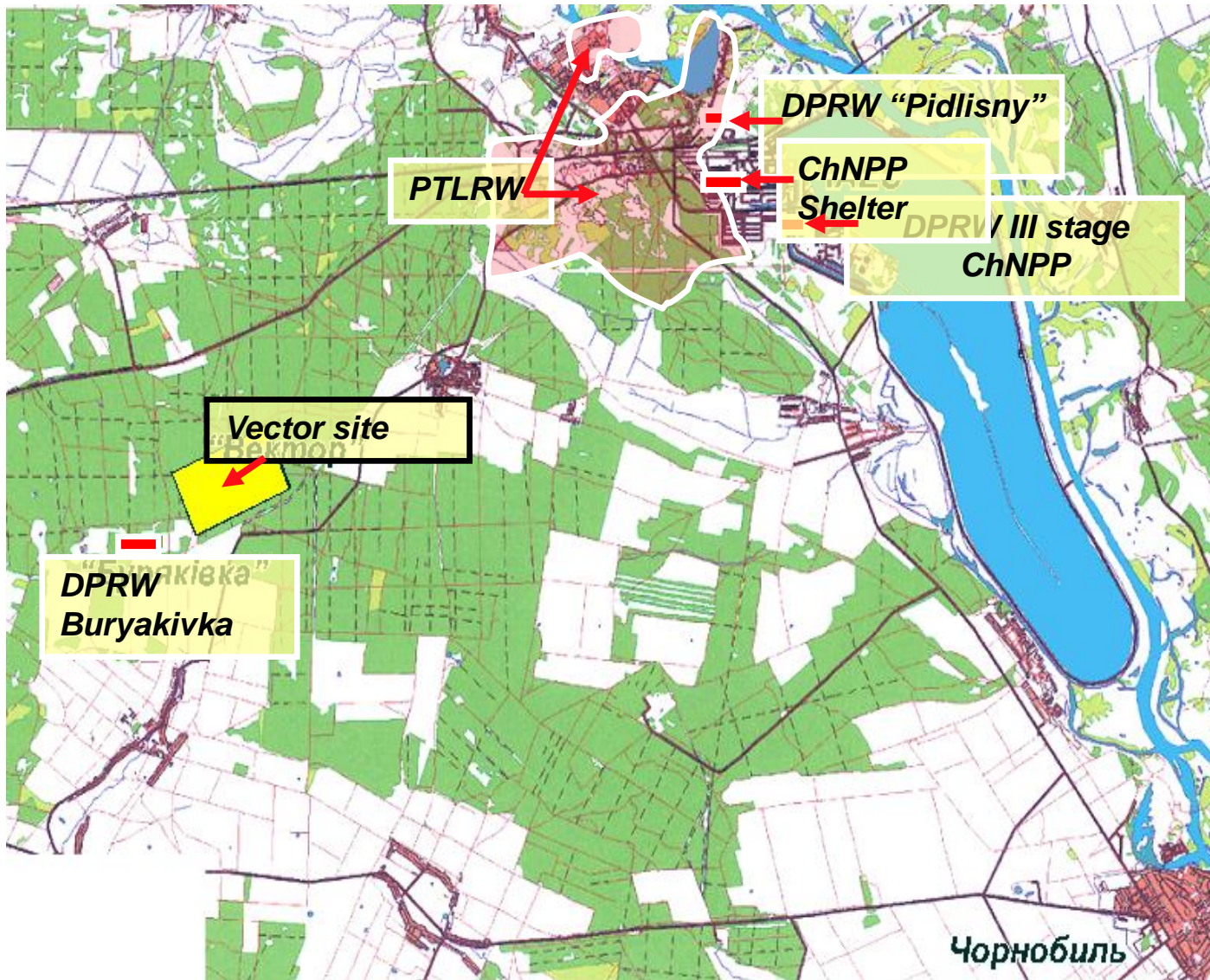
- **Near-surface disposal facilities for low-level short-lived RW**
- **Long-term storage facilities for long-lived and high-level waste**
- **Technological complex for RW treatment**

# Helicopter View of Vector site





## Vector site in Exclusion Zone



- 11 km to the south-west from ChNPP

## Exclusion Zone specificities

- **Inhabitants were evacuated in 1986**
- **Forbidden for living, provide agriculture and any other business**
- **Under special regime of management by State Agency of Exclusion Zone Management**
- **The only provided activities are accident liquidation, RW management, radiation control and monitoring**
- **Long-term status of the multy facilities territory located in Exclusion zone shall be officially defined**
  - **establishment of the territory of restricted access in long term application is planed**

# Comprehensive Safety Assessment of Vector Site

- **General radiological impact of existing and planned facilities on Vector site should be assessed including long-term period**
- **The SNRIU under EC INSC Project U3.01/08 involving experience of European TSOs has developed Guidance for the Comprehensive safety assessment of multiple facilities at Vector site**



# Guidance for the Comprehensive Safety Assessment established three periods of assessment:

- **I Period** – operational period while construction, operation, decommissioning, closure of RW management facility – **duration 200 years**
  - **II Period** – active control while monitoring, maintenance, repair of the disposal cup, restricted access to the territory – **duration 300 years**
  - **III Period** – passive control (restricted access),
    - continues degradation of engineering barriers
    - later may be no restriction
- **long-term duration**

# Comprehensive Safety Assessment of Vector Site

## The main issue of Comprehensive safety assessment

- to determine what maximum total activity of radionuclide may be disposed at Vector site
- feasibility to dispose at Vector site of all RW streams from Ukraine

## Assessment Presumption

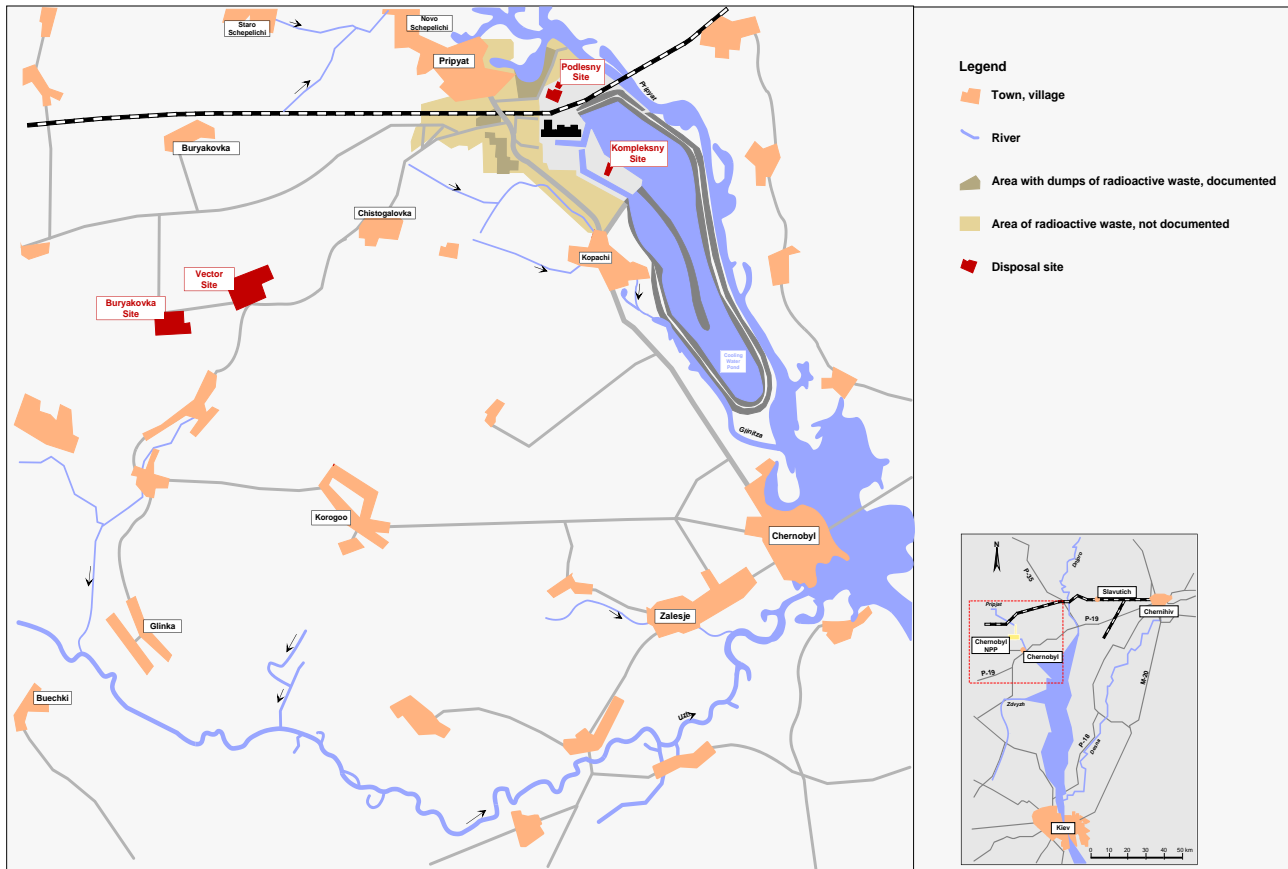
- **90%** of all RW in Ukraine is located in Exclusion Zone
- **Total activity** could be estimated as 5% of fuel of destroyed ChNPP Unit 4 –  **$2,5 \cdot 10^{16}$  Bq**
- Respectively to the Chernobyl RW inventory the total activity of main dose-forming radionuclides could be estimated as:
  - **$^{90}\text{Sr}$  –  $5,2 \cdot 10^{15}$  Bq**
  - **$^{137}\text{Cs}$  –  $11,6 \cdot 10^{15}$  Bq**
  - **$^{239}\text{Pu}$  –  $6,8 \cdot 10^{13}$  Bq**

# Comprehensive Safety Assessment of Vector Site

The scenarios which lead to the most significant impact of disposed waste in long-term period after closure are:

- Scenarios of radionuclides migration with groundwater – NES – Periods II and III
- Scenarios of spreading of radionuclides with air coursed by Tornado – alternative scenario – Period III
- Dose criteria applied:
  - for normal evolution scenarios – 0,3 mSv/year
  - for alternative scenarios – 1 mSv/year

# Scenarios of radionuclides migration with groundwater



Vector site located

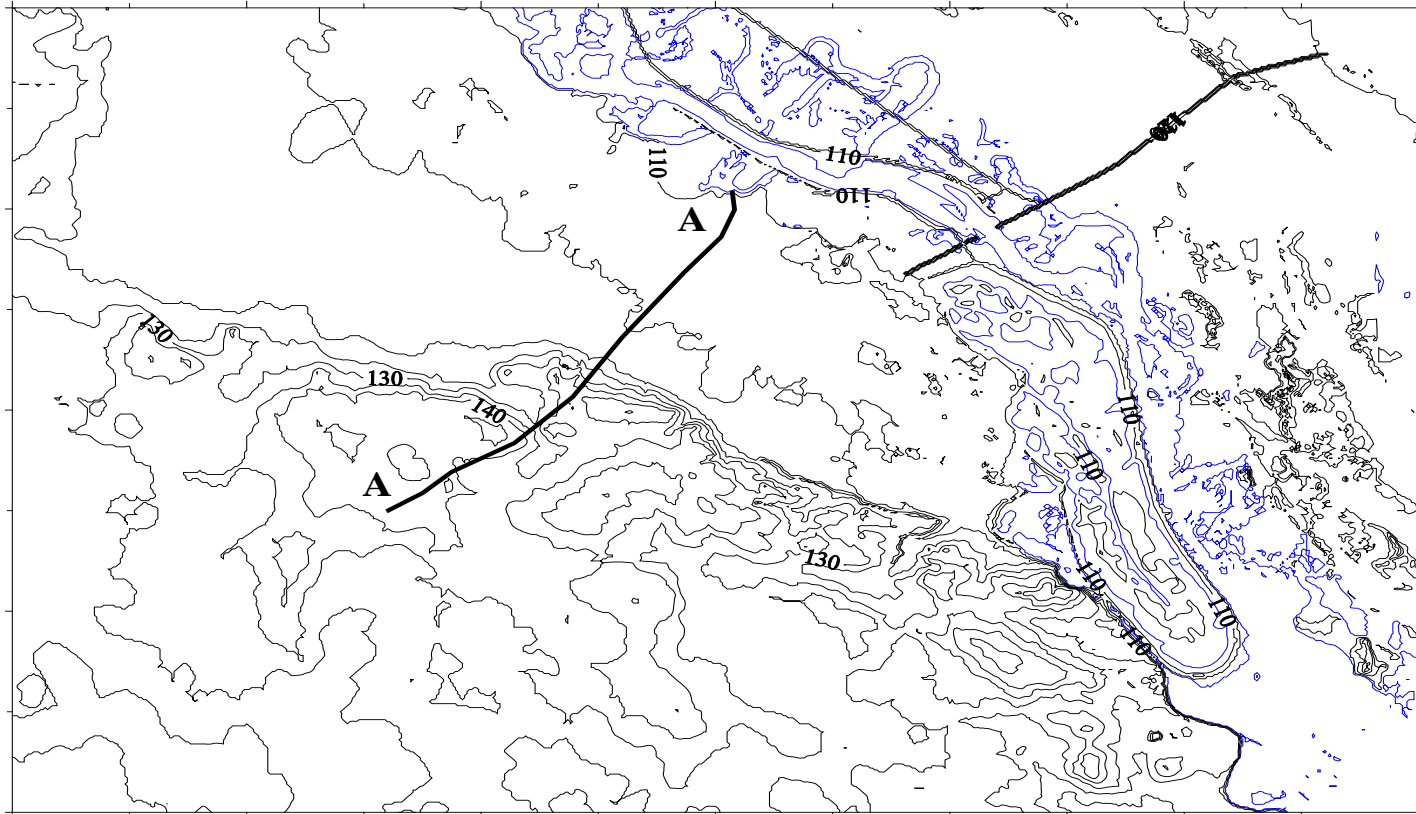
- At watershed of Prypyat and Uzh rivers
- At a distance of 8 Km from Prypyat river
- At a distance of 18 Km from Uzh river

## Scenarios of radionuclides migration with groundwater

- Within TACIS Project U3.02/00 (UK/TS/25) for the facility constructed at the Vector site for disposal of RW of ChNPP have been assessed
  - migration of radionuclides with ground water to the places of discharge near Prypyat' river
  - doses for the critical groups of population residing at this territory were estimated
- The hidrogeological model of disposal at Vector site was considered



# Scenarios of radionuclides migration with groundwater



- Level of the first aquifer is at a depth from 15 to 21 m
- Underground water pathway to the north-east to the Prypyat river **A-A**

# Scenarios of radionuclides migration with groundwater

## Model assumptions:

- radionuclides are transferred to the aquifer in vertical direction only through the elements of the near field (disposal structures, natural foundation)
- the critical group of population is located at the place of ground water discharge at a distance of about 7000 m from the Vector site (this distance may be considered as the size of restricted access area)
- for dose estimation all dose pathways in biosphere for members of the critical group in the places of ground water discharge were considered

# Scenarios of radionuclides migration with groundwater

- Taking into account the results obtained in UK/TS/25 and assuming disposal at the Vector site of Chernobyl RW of total activity  $2.5 \cdot 10^{16}$  Bq
- At a distance of  $\approx 7000$  m, maximum impact of
  - $^{90}\text{Sr}$  is observed in  $\approx 220$  years with dose estimated as  $\sim 52$  mSv/year
  - $^{137}\text{Cs}$  in  $\approx 300$  years, and dose is  $\sim 8.8$  mSv/year
- The period up to 500 years will belong to the active control of the Vector site (**Period II**) when cap integrity is maintained, environment is monitored, etc. Within this period, it is unlikely that the area of existing Exclusion zone will be reduced significantly
- Therefore, safety of  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  disposal for a long term may be ensured taking into account measures of active control and Exclusion zone barrier function
- However these estimates are made with a high degree of conservatism and it is necessary to carry out detail studies on properties of engineering and natural barriers, scenarios for migration of nuclides

# Scenarios of radionuclides migration with groundwater

- At a distance of  $\approx 7000$  m, maximum impact of
  - $^{239}\text{Pu}$  is observed in  $\approx 17400$  years, and dose estimated as  $\sim 160$  mSv/year (much exceeds limit)
- Contrary to  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$ , during the period when significant impact of  $^{239}\text{Pu}$  is expected, there will be no active control of the Vector site
- For the period of time more than 10,000 years, it is not possible to rely on the existence of restricted access area and integrity of the disposal systems
- However, these estimates are made with a high degree of conservatism and it is necessary to carry out detail studies on properties of engineering and natural barriers, scenarios for migration of nuclides
- $^{239}\text{Pu}$  migration will be determined by sorption capacity of geological layers under disposal and characteristics of aquifers (first and second).

The properties of natural barriers

- will limit  $^{239}\text{Pu}$  migration to acceptable levels
- ensure a sufficient level of  $^{239}\text{Pu}$  "dilution" during migration in geosphere

# Scenarios of spreading of radionuclides with air coursed by Tornado

- Tornado of the intensity up to F 3.0 class happened and may occur in this region
- The probability of
  - F 3.0 class tornado is estimated as  $10^{-6}$ /year
  - F 1.5 class – as  $10^{-5}$ /year
- F 3.0 class tornado happened on 11.06.2001 in the region close to Exclusion Zone
- In SIP Project the estimations were made for real meteorological conditions of this tornado presuming it happened on Shelter Object

# Scenarios of spreading of radionuclides with air coursed by Tornado



- Rough estimation for Vector site was made on the basis of the results obtained for the Selter Object
- Long-term period is considered when significant degradation of engineering barriers and surface erosion could take place (10 000 and 100 000 years)
- The path width of F 3.0 class tornado is 290 m Estimated part of activity taken by tornado from Vector site = Total activity ( $2,5 \cdot 10^{16}$  Bq)  $\times 2 \cdot 10^{-3} = 5 \cdot 10^{13}$  Bq



# Scenarios of spreading of radionuclides with air coursed by Tornado



- Due to presumed Tornado elevation of waste particles to height of  $\approx 1000$  m
- Modeling of spread of waste particles into atmosphere and following precipitation to the territory shows
  - max contamination at 12 km distance (out of restricted zone)
- Pathways of human exposure
  - inhalation of radionuclides
  - ingestion of small particles
- Potential dose estimated for
  - period 10,000 years – 6.9 mSv/year (exceeds limit of 1 mSv/year)
  - period 100,000 years 0.27 mSv/year

# Scenarios Conclusions

- Conservative estimations for the presented scenarios have not showed significant safety margin by dose indicators for disposal at Vector site of RW of Total activity  $2,5 \cdot 10^{16}$  Bq
- On the other hand, the possibility for disposal of low-level and some part of intermediate-level waste of Chernobyl origin at the Vector site caught not be excluded
- Rough conservative assumptions in scenarios should be clarified and more realistic parameters and assumptions should be used for assessment
- Therefore, it is necessary to carry out detail studies and analysis of features, events and processes that may lead to release of RW to the surface of the site using updated realistic parameters

# Comprehensive Safety Assessment of Vector Site

- Development of such assessment and decision of issues mentioned is the presentation is expected within industrial INSC Projects planned according the “Strategic Road Map of RW management” within annually Action Plans:
  - AP-2010 - **U4.01/10-F** “Comprehensive safety assessment of radioactive waste management facilities in the Chernobyl Exclusion Zone”
  - AP-2011 - **U4.01/11-B** “Full license for Lot 3 and Type I and II Vector disposal facilities”