EM International Program Modeling Activities

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Performance Assessment Community of Practice Technical Exchange
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Outline

- **Review of projects formerly supported by DOE-EM**
- **Potential International Projects and Analogue Case Studies for ASCEM**
  - **Chernobyl Cooling Pond, Ukraine**
  - **Nonclassical transport modeling—project with the Nuclear Safety Institute of RAS, Russia**
  - **Uranium Mine and Mills Tailing’s Covers**
    - **Central Asia--**Kazakhstan, Tajikistan, Kyrgyzstan, and Uzbekistan
  - **Cementitious Materials for Long-Term Storage and Disposal**
- **Conclusions and Recommendations**

Overall Objectives of DOE-EM International Program Modeling Activities

- **Use international experience and relevant analogue case studies to support the development and to improve the capability of DOE fate and transport models.**
- **Assist in designing effective remediation technologies for contaminated soils and groundwater.**

DOE-EM Funded Projects

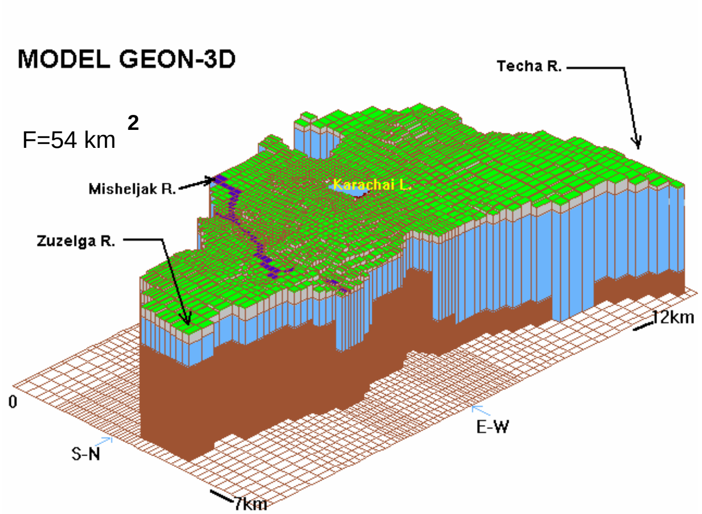
In November 1990, the DOE and MINATOM of Russia established a Joint Coordinating Committee for Environmental Restoration and Waste Management (JCCEM).

Project Title	Duration		Principal Investigators	
	From	To	USA	Russia
1. Characterization of Contaminated Territories, Monitoring Networks, Optimization, and Cost Minimization	2000	2002	S.McKenna, SNL	M.Kanevski, Nuclear Safety Institute, Moscow
2. Uncertainty Assessment and Development of Inverse Flow and Transport Models	2000	2002	C. Murray, PNNL	M.Kanevski, Nuclear Safety Institute, Moscow
3. Uranium Transfer Phenomena in Welded Tuffs	2000	2002	F. Perry, LANL	V. Petrov, Institute of Geology of Ore Deposits, and Geochemistry
4. Modeling Migration of Radioactive and Chemical Wastes Through the Vadose Zone	1999	2003	B. Faybishenko, LBNL	V. Kurochkin, "Oreol"
5. Models for Deep Well Injection Sites of Liquid Radwastes (Tomsk project)	2001	2005	S. Wurstner, PNNL	Vitaly Kurochkin, "Oreol"
6. Mayak Contaminant Plume Model	1995	2003	S. Wurstner, Mi.Foley, PNNL	M. Glinsky, Hydro-spetzgeologiya and E.Drozhko, Mayak

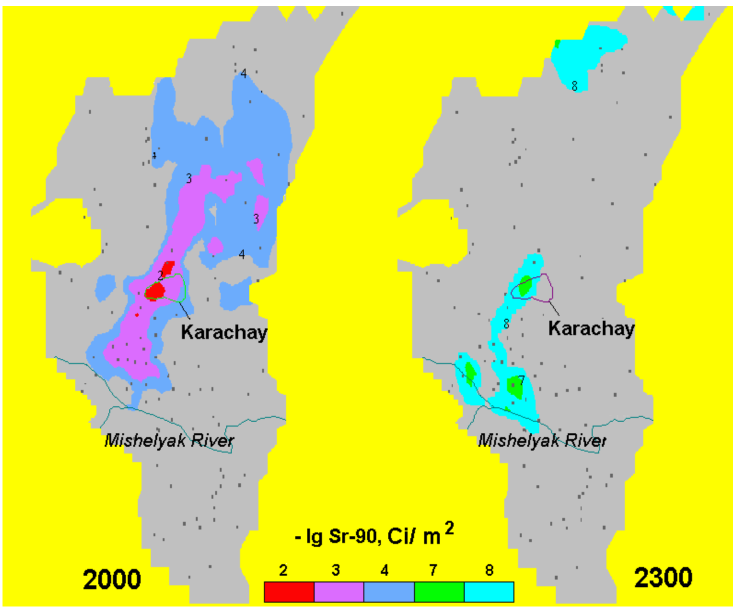
Modeling of Radioactive Contaminant Transport in Saturated and Unsaturated Zones at Nuclear Waste Disposal Sites

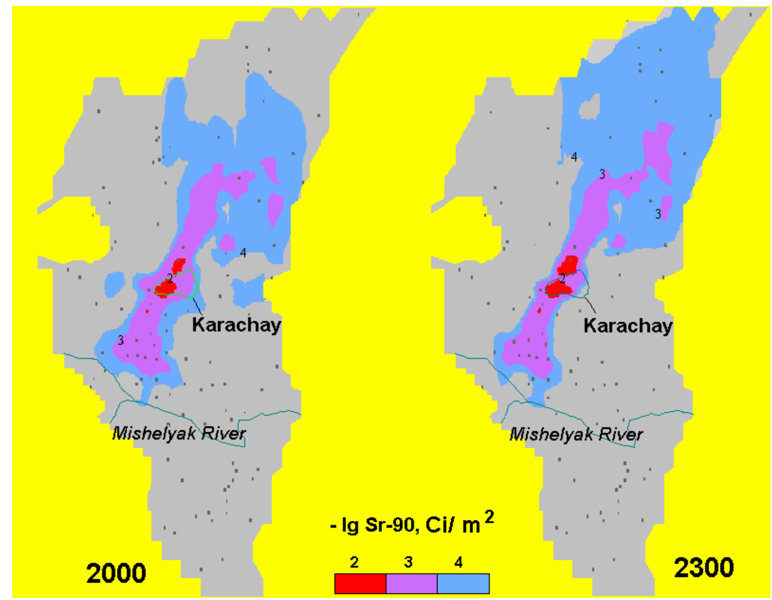
Collaboration between Minatom of Russia and DOE

Prediction of ^{90}Sr-90 plume evolution in groundwater from Lake Karachay



K_d of fractured rocks based on 30-yr monitoring of Sr-90 in groundwater

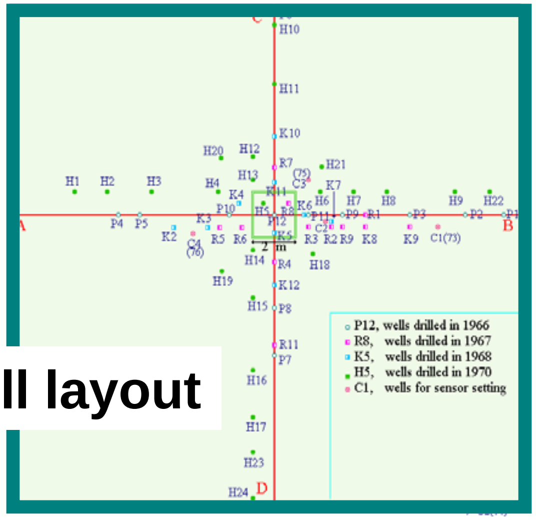




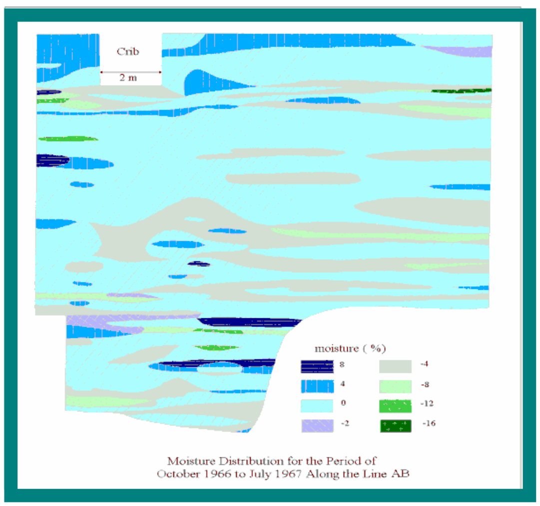
Reservoir containment – no migration to groundwater.

Continuous discharge of ^{90}Sr from the reservoir is 600 Ci/yr.

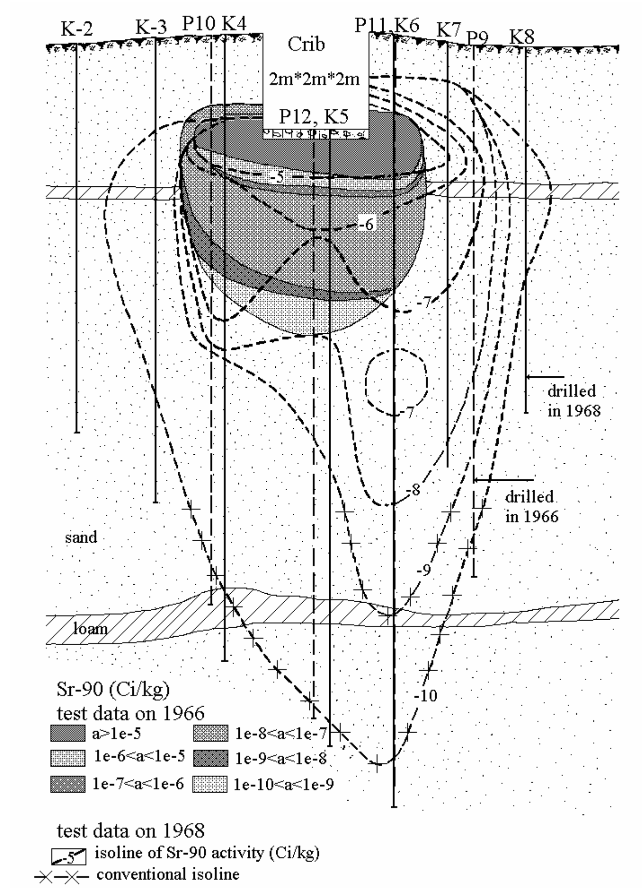
Field Infiltration Test Using ^{90}Sr near the Novo-Voronezh NPP



Well layout

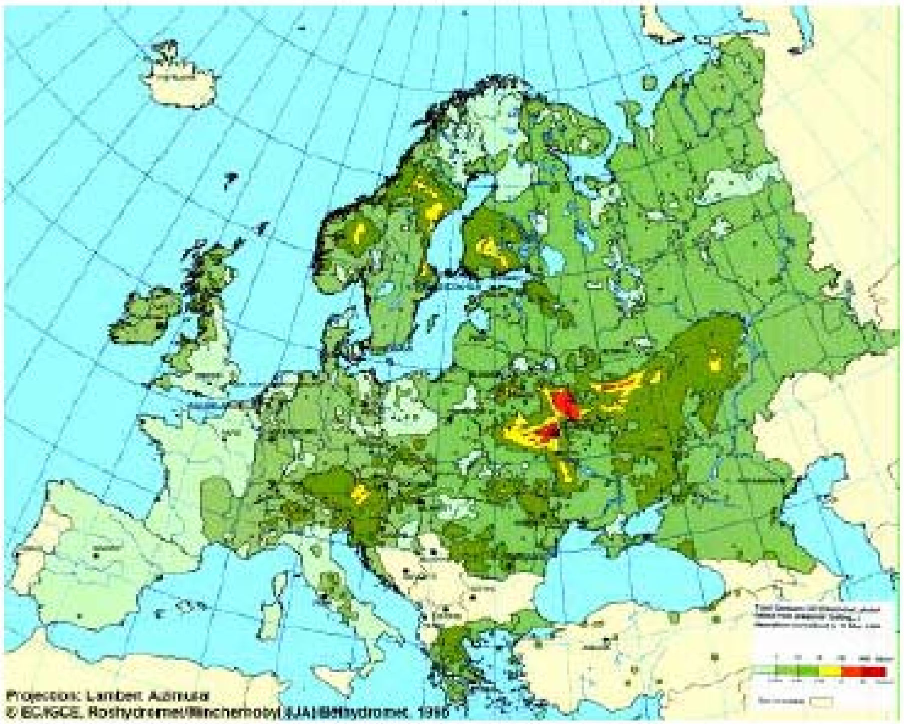


Moisture distribution below the crib



Sr-90 distribution below the crib

Chernobyl Accident is the Highest Single Release of Radionuclides into the Global Environment



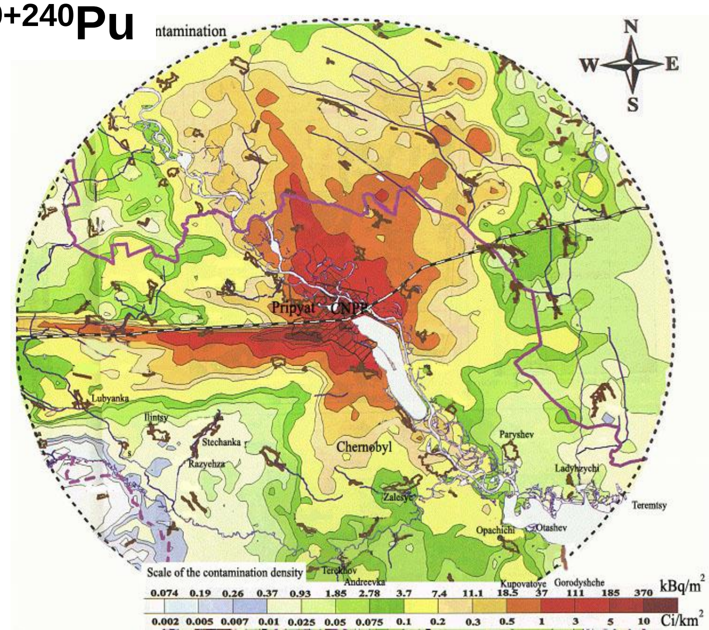
- Relatively short-lived isotopes of iodine, cesium, and strontium
- Long-lived transuranic elements such as plutonium and americium
  - ~2,000 Ci of of $^{239,240}Pu$

We don't need to guess--we know what happened at Chernobyl, and can use this information as an analogue to build confidence in flow and transport models and risk assessment

Chernobyl Exclusion Zone is an area that was sealed off as an institutional control to prevent further access after the accident.

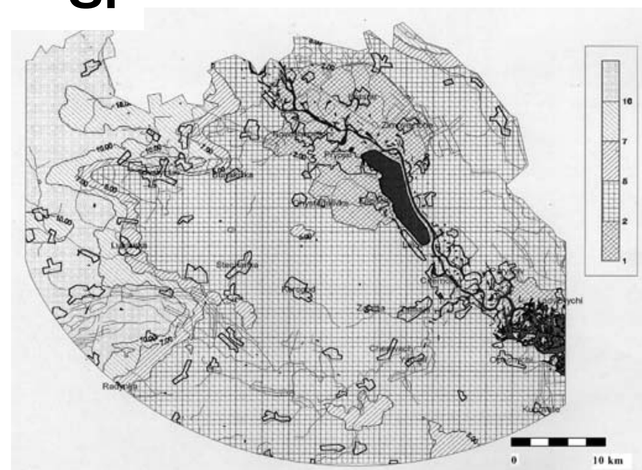
Maps of Pu, Sr and Cs Surface Contamination within the ChEZ in 2000

$^{239+240}Pu$

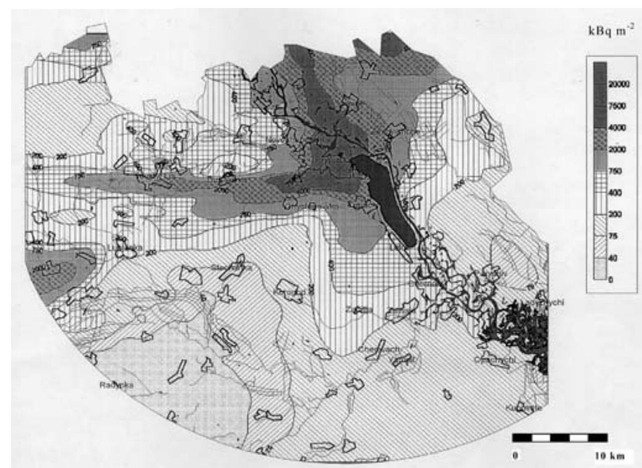


~99% of plutonium accumulated within the top 2 cm layer

^{90}Sr



^{137}Cs

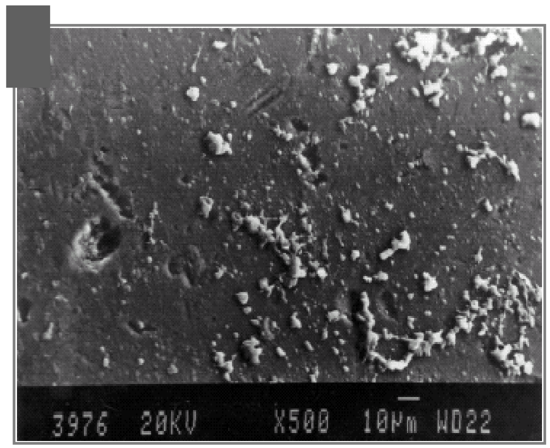


Challenging Problem-- Released Radioactive Particles

- **Fuel components** of finely dispersed fuel particles
  - Low volatility elements, such as cerium, zirconium, barium, lanthanum, strontium, and the actinides
  - Settled primarily within the ChEZ
- **Condensed components**
  - Formed when radioactive gases ejected during the nuclear fuel fire, such as iodine, tellurium, cesium, and strontium, and ruthenium
  - Settled primarily along the atmospheric flow pathways.

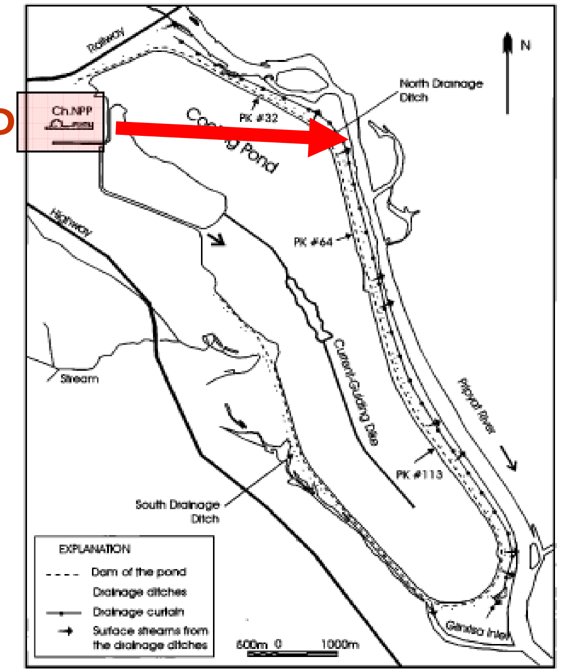
- **Hot particles**

• Fuel particle, uranium dioxide, with a specific activity > 10^5 Bq/g.
• Size from 1 to 100 μm, surface density ~ 1,600 per m2
• Detected in soils to depths of about 0.5 m



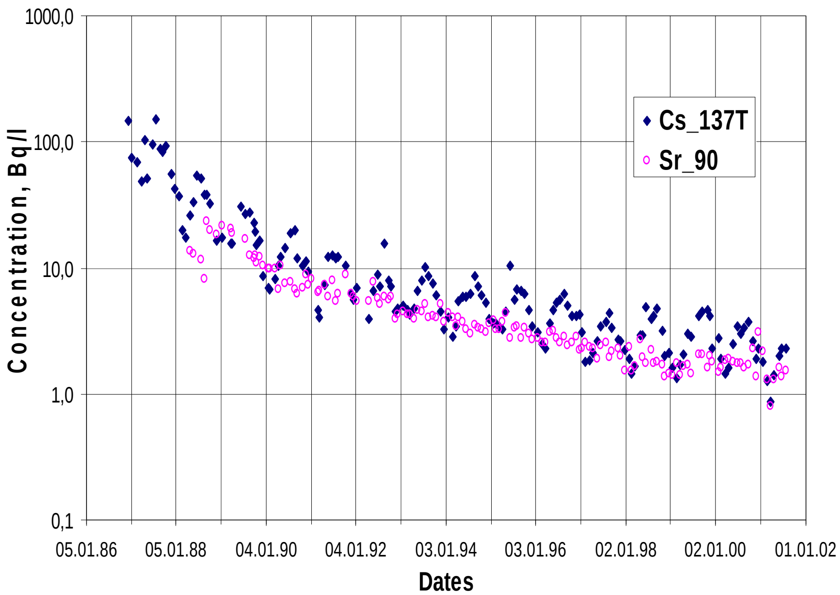
Chernobyl Cooling Pond

ChNPP

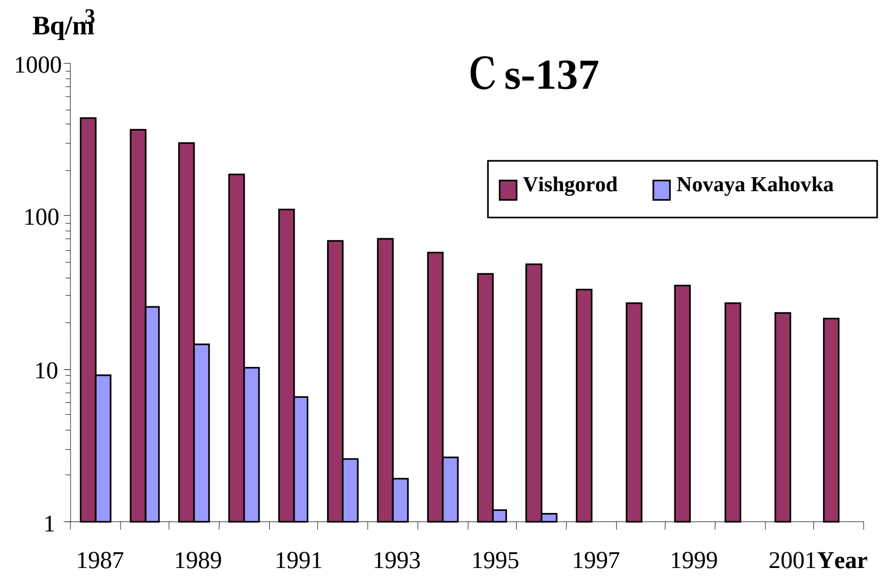


- **Area = 22 km^2**
- **Water is pumped from the Pripyat River to the CP**
- **Water level is 6 -7 m higher than an average River level**
- **After the decline of the CP water level, sediments will be exposed**

^{137}Cs and ^{90}Sr Concentrations in the Chernobyl Cooling Pond

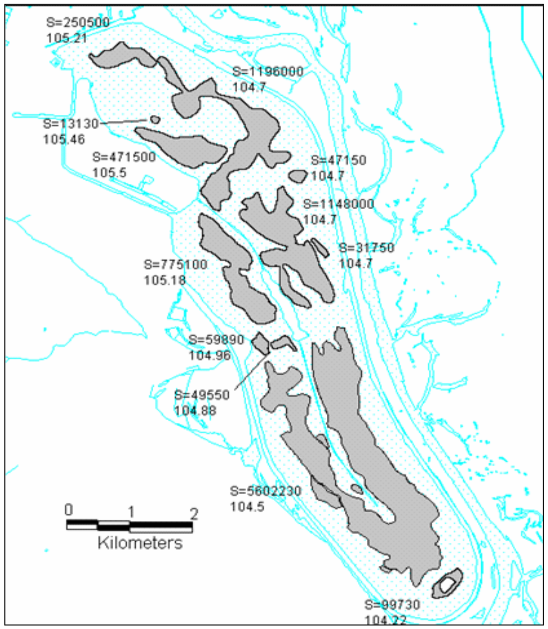


Concentration of ^{137}Cs vs. Time in Two Reservoirs of the Dnieper Cascade.

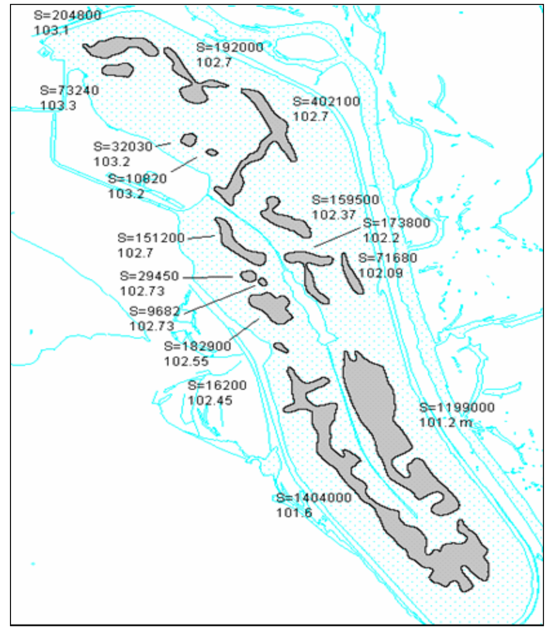


Expected Areal Distribution of Exposed Sediments During the Pond Water-Level Drawdown

Normal climatic scenario



Dry climatic scenario



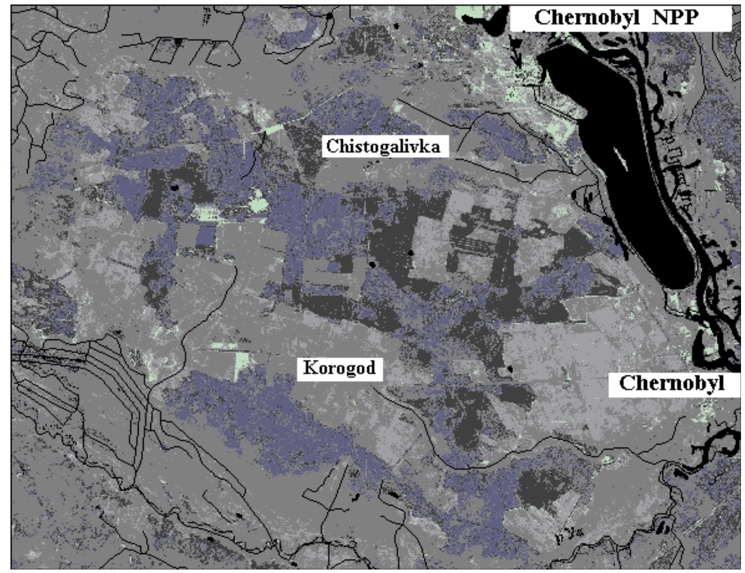
- **After the water level drawdown, up to 15 km^2 of the sediments will become exposed and may need stabilization and remediation.**

Extreme Climatic Scenarios

Increased Frequency of Flooding Events

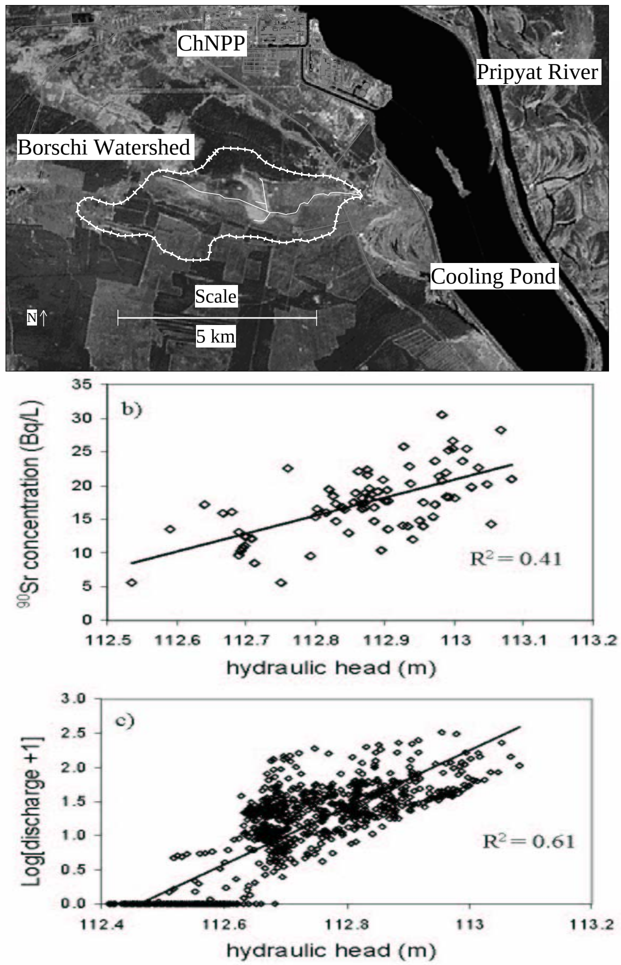
SURFACE FLOODING AT THE NEFTEBAZA PVLRO

Increased Fire Risk



V.I.Lyalko et al., Satellite monitoring of forest of the Chernobyl disaster…
International Archives of Photogrammetry and Remote Sensing. Vol. XXXIII, Part B7. Amsterdam 2000.

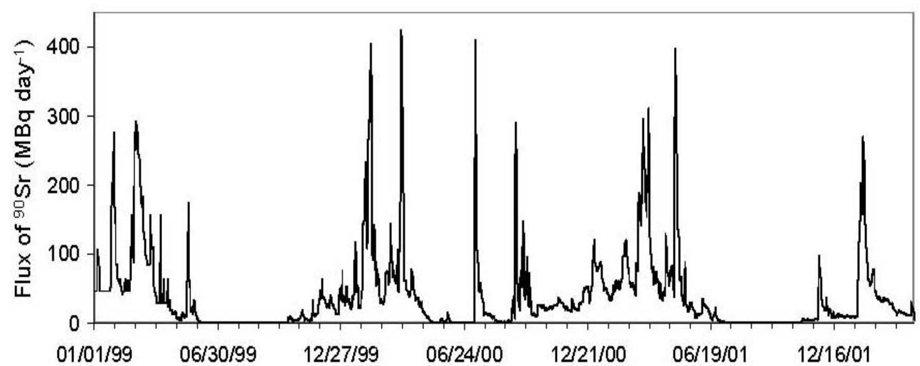
Potential Case Study -- Borschi Watershed



Freed et al., 2004, Seasonal Changes of the 90Sr Flux in the Borschi Stream, Chernobyl, ERSP, 2003

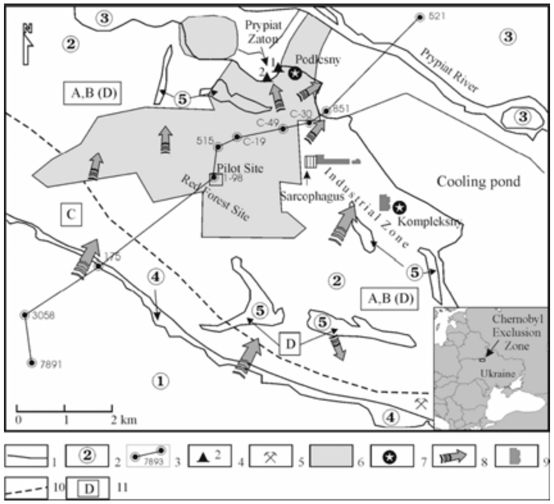
- Correlation of ^{90}Sr concentration and discharge at the mouth of the Borschi stream and hydraulic head

^{90}Sr flux in the Borschi stream

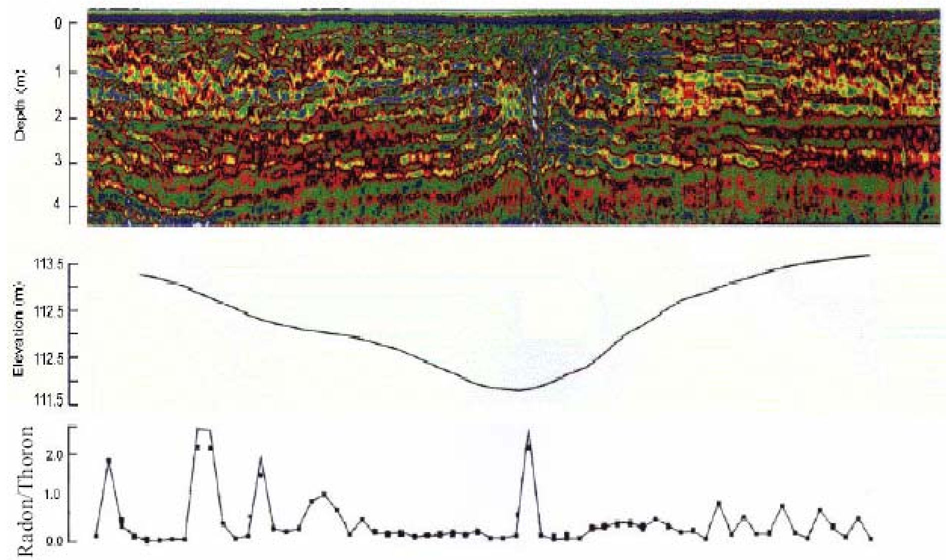


Potential Case Study –
Vadose Zone Flow and Transport

Chernobyl Pilot Site

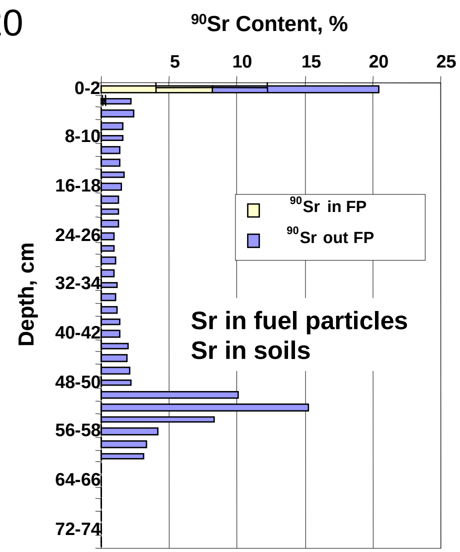


A.Matoshko et al, 2004,
D.Bugai et al., 20



Comparison of surface radar tomography and Radon/Thoron isotopic methods to determine zones of preferential flow

Shestopalov et al., 2000



- **Vertical velocity of ^{137}Cs migration was 0.4 to 0.7 cm/yr in the first years after the accident, and then dropped to 0.2 cm/yr**

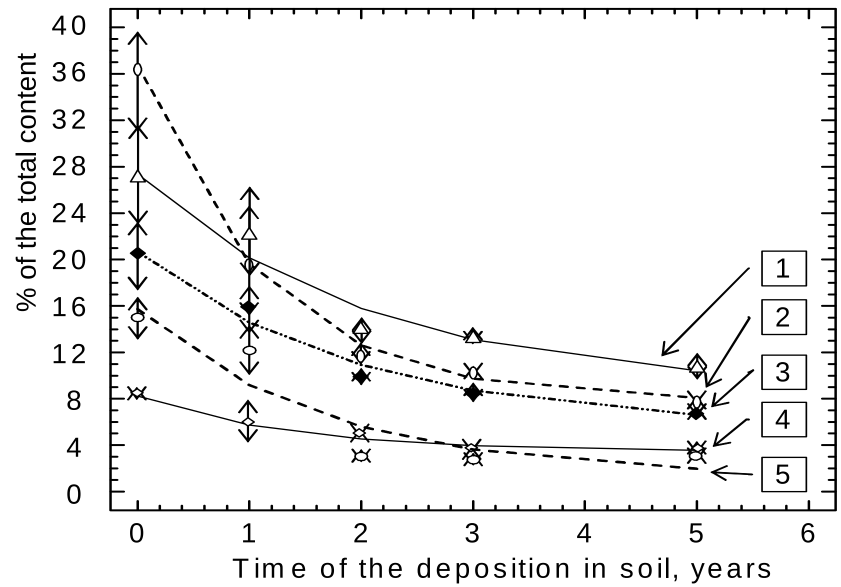
Estimated Ecological Half-Life of Radionuclides in Soils

<u>Radioactive decay</u>, <u>biogeochemical processes</u>, and <u>migration</u>, depending upon the types of soil and particles released.

- **^{137}Cs-137, from 28±14 to 300±110 years;**
- **^{90}Sr, from 21±15 to 230±130;**
- **^{154}Eu, from 26±11 to 460±270,**
- **^{241}Am, from 25±10 to 460±220;**
- **Pu, from 100±45 to 260±120.**

K_d's are variable with time

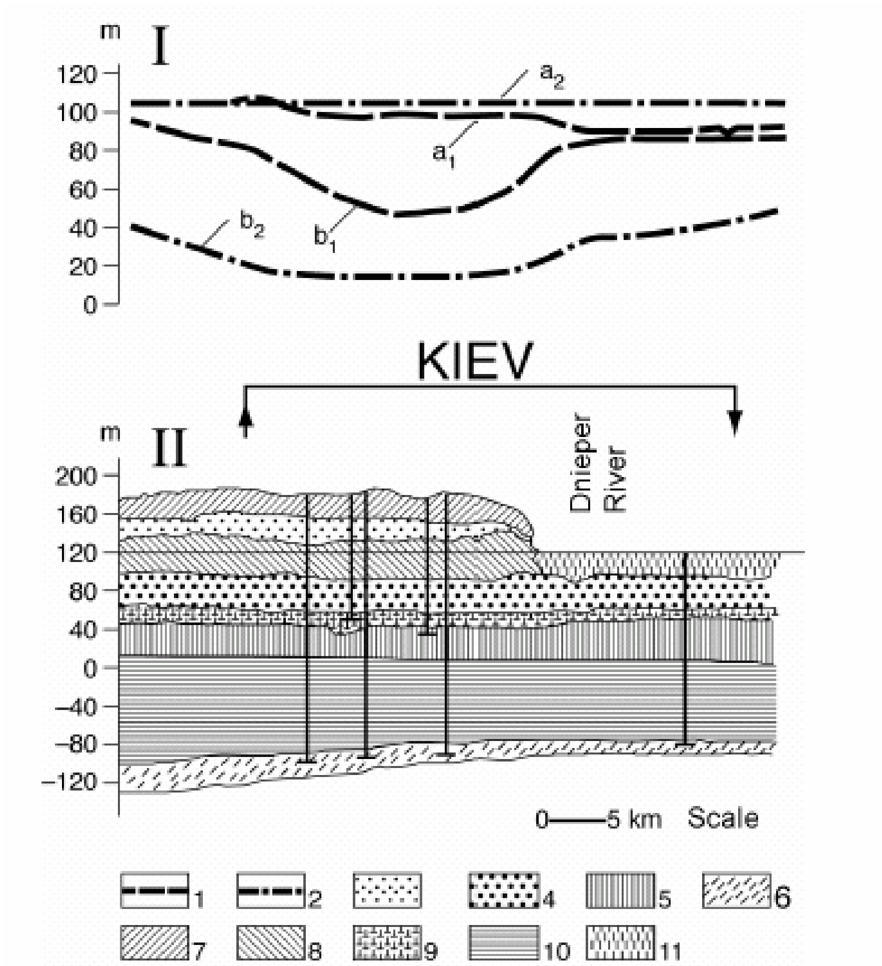
^{137}Cs Concentration Introduced Into Soil in a Water-Soluble Form

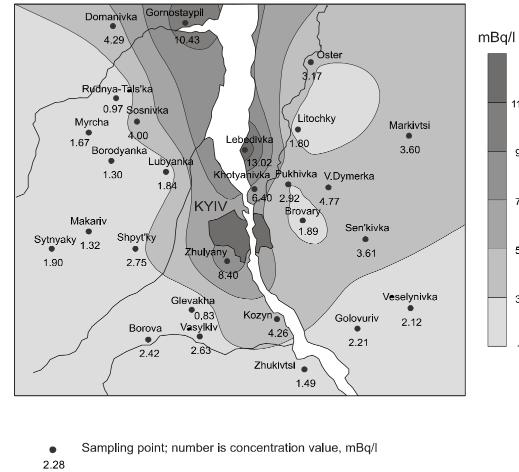


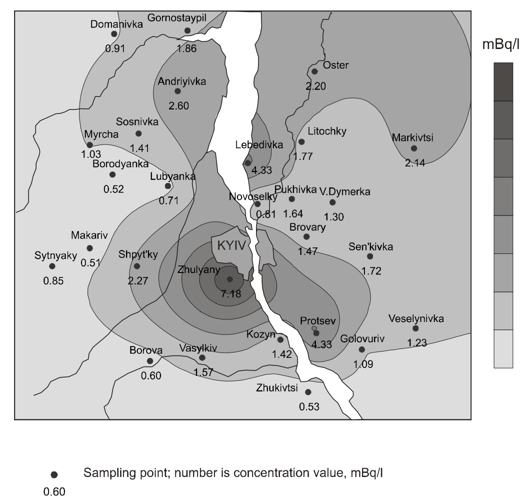
1 – Arable land; 2– Sandy-loam soil (arable land after liming in very high doses); 3 – Sandy-loam soil (arable land); 4 – Sandy-loam humus soil (meadow); 5 – Sandy-loam soil (arable land);

(Ivanov and Kashparov, 2004)

^{90}Sr and ^{137}Cs Groundwater Contamination in all Aquifers to 200–300 m Depths





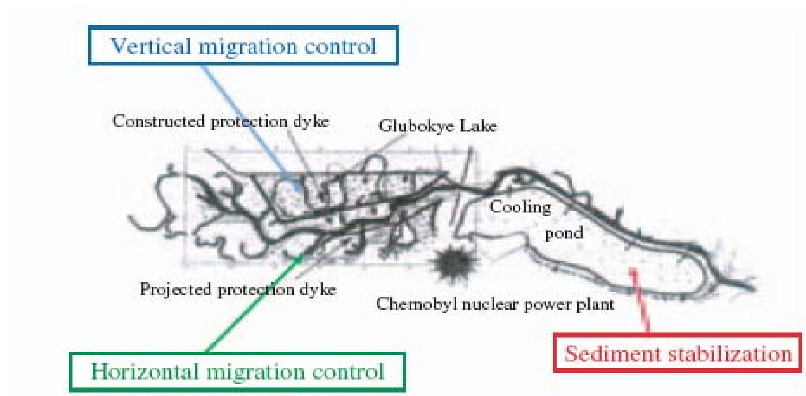


Preferential flow?
Flow through borehole annulus?

^{90}Sr in Quaternary (7--20 m depths) and Eocene aquifers (30–60 m depths) in 1996

Potential Remediation Approaches

- Phytoremediation
- Excavation & Disposal
- Capping
- Immobilization/stabilization
- Bioremediation
- "No action" approach & Institutional control



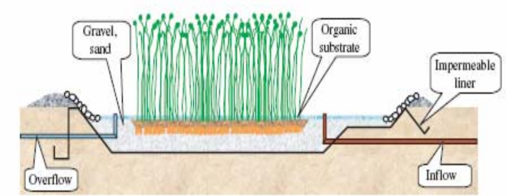
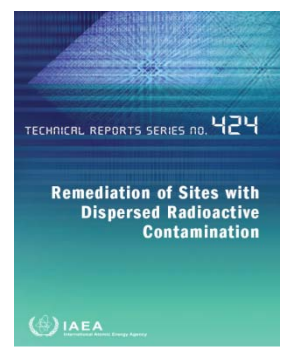
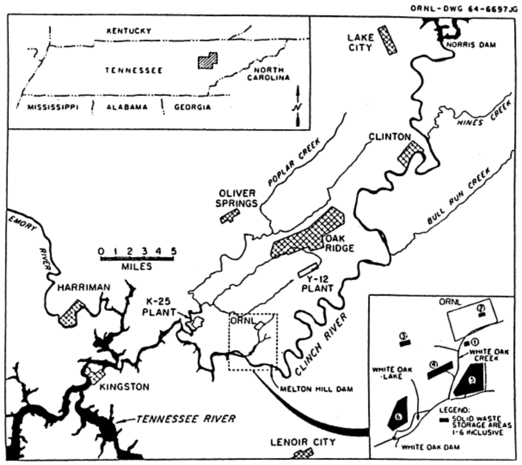


FIG. 15. Schematic cross-section of a constructed wetland.

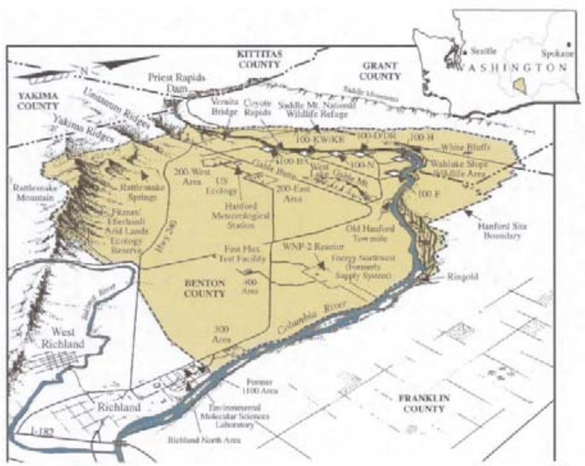
IAEA Chernobyl Cooling Pond decommissioning and remediation roadmap



Surface Water-Groundwater Contamination Problems at DOE Sites



Oak Ridge



Hanford

Site.

Savannah River PAR Pond

C.T. Garten Jr.a, D.M. Hambyb,U, R.G. Schreckhise, Radiocesium discharges and subsequent environmental transport at the major US weapons production facilities, The Science of the Total Environment 2552000.55-73

Numerical Modeling of Contaminant Transport Processes in Geologic Media to Support the Development of the Advanced Simulation Capabilities for Environmental Management (ASCEM)

Nuclear Safety Institute (IBRAE) of the Russian Academy of Sciences has conducted research with DOE since 1997

Overall Objective: Support the next generation of performance assessment models for simulating nuclear waste disposal in geologic media.

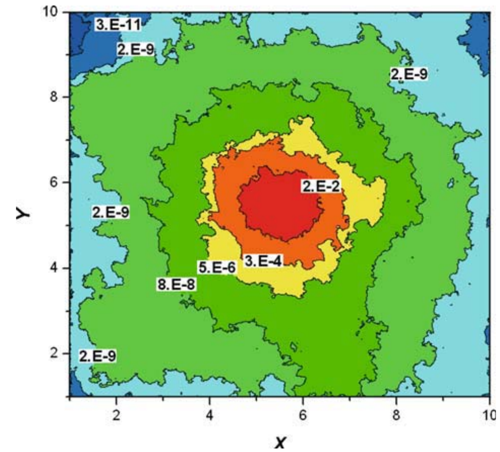
Expected Results: IBRAE will develop novel transport models and numerical methods for integration of nonclassical models into the ASCEM simulators.

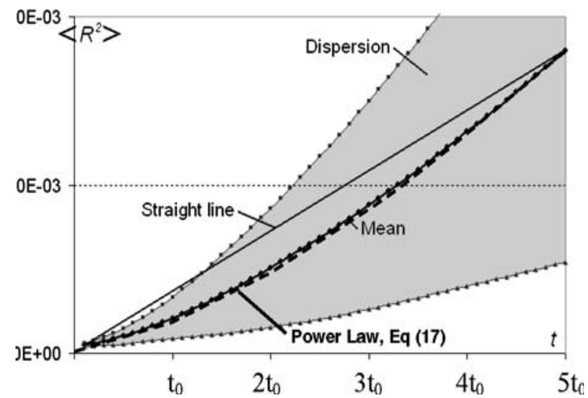
DOE-EM Project Manager--Ming Zhu

Transport Phenomena in Highly Heterogeneous Media can be Dramatically Different from those in Homogeneous Media

- Anomalous transport may govern the rate of migration and degree of dispersion of groundwater contaminants from hazardous waste sites.

- “CABARET” - Compact Accurate Boundary Adjusting high-REsolution Technique).
  - Combines finite-volume and finite-difference approaches to simulate advection processes.
  - Generalizes the dual-porosity model for infiltration and solute transport in unsaturated rocks, taking into account fractal aspects of the percolation process





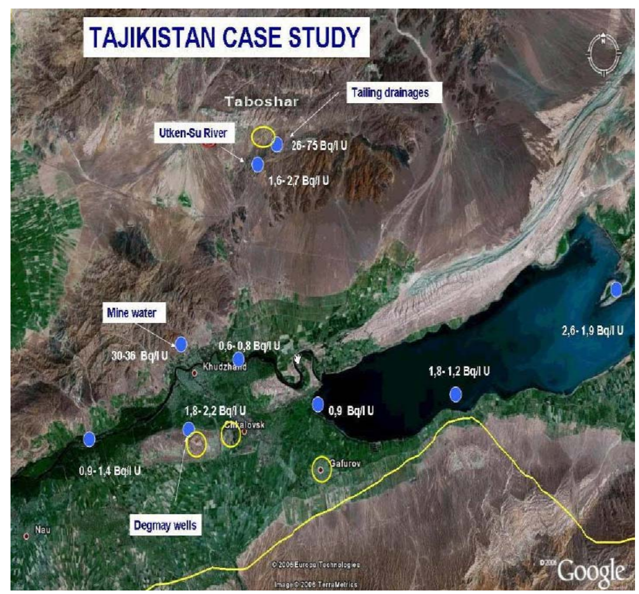
The mean and dispersion of the mean-square radius of the concentration cloud as a function of time in a super-diffusion regime,
V.M. Goloviznin et al., A novel computational method for modelling stochastic advection in heterogeneous media, Transp Porous Med (2007).

Potential Case Studies of Uranium Mine and Mills Tailing's Covers and Barriers in Central Asia

Mailuu Suu , Kyrgyzstan - April 2007

R. Edge and O.Voitsekhovych, Environmental Management and Remediation of the Uranium Production Legacy in the Central Asia (Weaknesses, Needs and Challenges), Kick-off Meeting of the Network on Environmental Management and Remediation Technical Meeting, November, 23-27, 2009, VIC, Vienna, Austria.

Koshkar-Ata radioactive and U-residue tailing, Kazakhstan



Cementitious Materials for Long Term Storage and Disposal

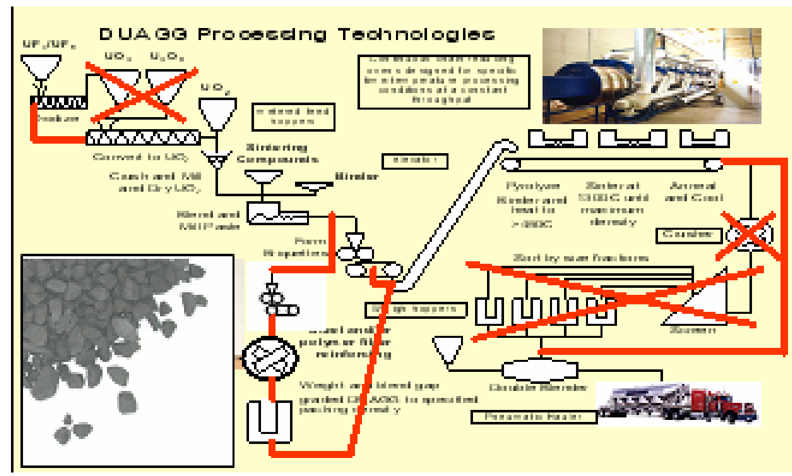
- **VNIINM (the A.A. Bochvar All-Russian Scientific-Research Institute of inorganic materials, Russia) and RFNC-VNIIEF (Russian Federal Nuclear Center–All-Russian Scientific Research Institute of Experimental Physics) developed high-density concrete with ceramic aggregate based on depleted uranium dioxide.**

- **SIA RADON--Cementitious composite for immobilization of radioactive waste into final waste form. 100,000 m³ of LRW treated on cementation plants.**

- **Implemented at Mining Chemical Combine (Zheleznogorsk, Krasnoyarsk-26), Mayak, and Tomsk-7 – where liquid wastes had been injected.**

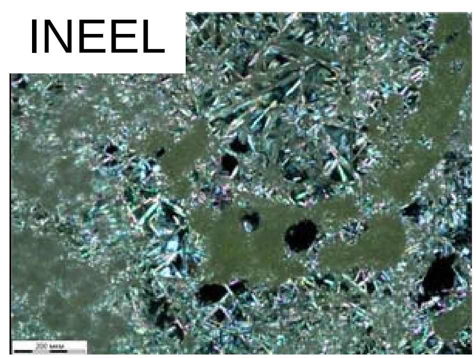
Ermichev et al., 9th Intern Conference on Environ Remediation and Radioactive Waste Management 2005, Glasgow, Scotland,

Ceramics production using the VNIINM technology and comparison with the STARMET technology

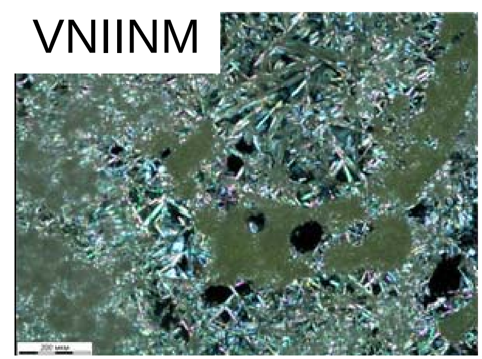


Pictures of bond samples

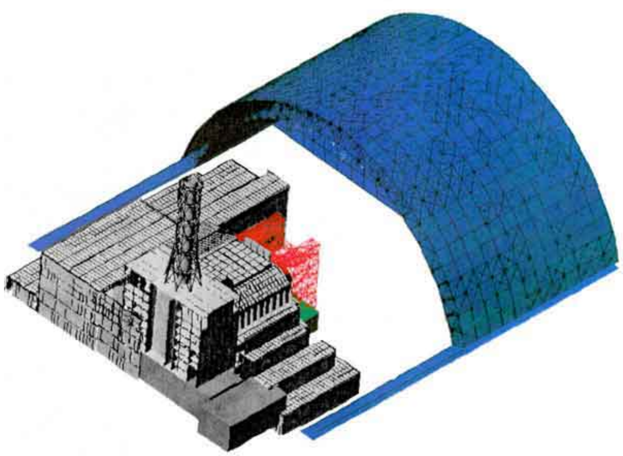
INEEL



VNIINM



Chernobyl Concrete Sarcophagus



- Erected in November 1986 with a designed lifetime of only 20 to 30 yrs.
- Stored radioactive waste activity is $2.4 \cdot 10^{20}$ Bq.
- >7,000 tons of steel and 410,000m^3 of concrete.
- Lack of stability and corrosion of supporting beams.
- Water leaking through the roof holes.
- Water seeping into the soil below.
- Gas and dust escape through the roof and wall cracks.
- Continuous monitoring and modeling.

Conclusions and Recommendations

- **International experience, databases, and case studies can be used as analogues to support the development of a high-performance computing platform and benefit the ASCEM Project:**
  - Thrust Area 1 -- Platform and Toolset Development,

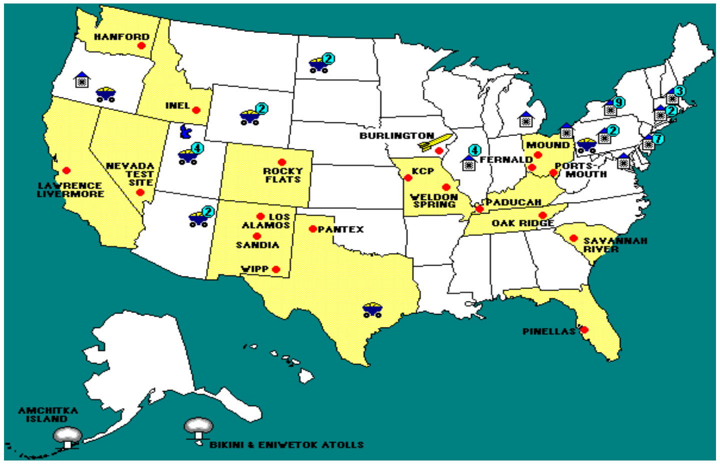
    i.e., Chernobyl Database
  - Thrust Area 2 -- Process Models and HPC Framework,

    i.e., nonclassical flow and transport modeling;

    uncertainty evaluation using modeling of the the Chernobyl Cooling Pond
  - Thrust Area 3 -- Site Application,

    i.e., site attributes

Conclusions and Recommendations



Relevance of EM International Modeling Program to DOE-EM Mission

- **Enabling DOE's Soil and Groundwater Cleanup Efforts**
- **Isolating Contaminants**
- **Ensuring Environmental Stewardship**
- **Controlling Contaminant Plumes**