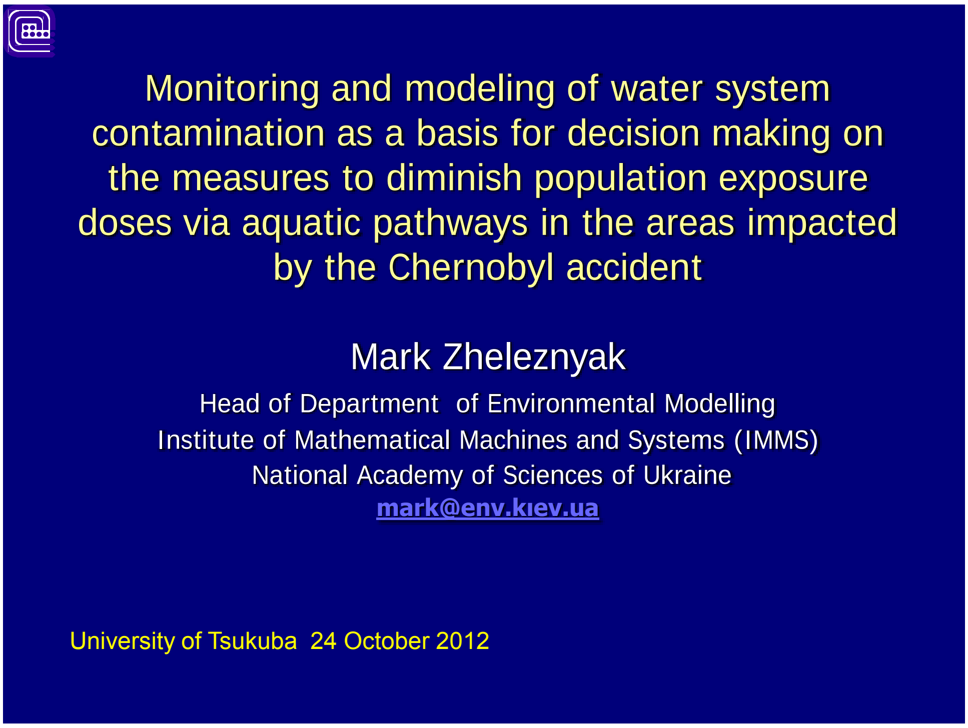
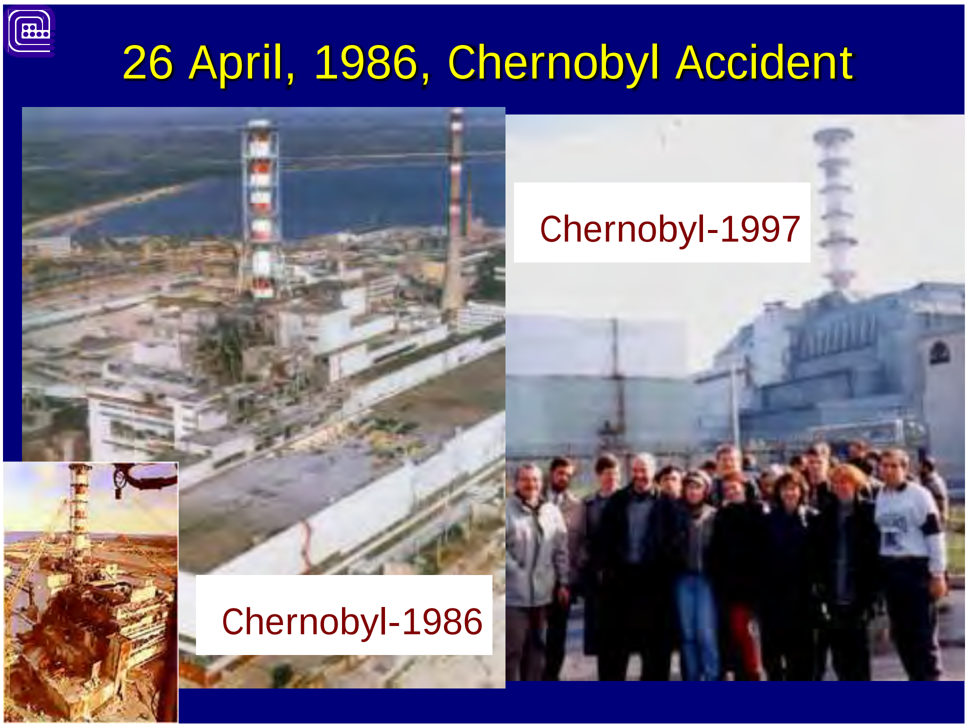
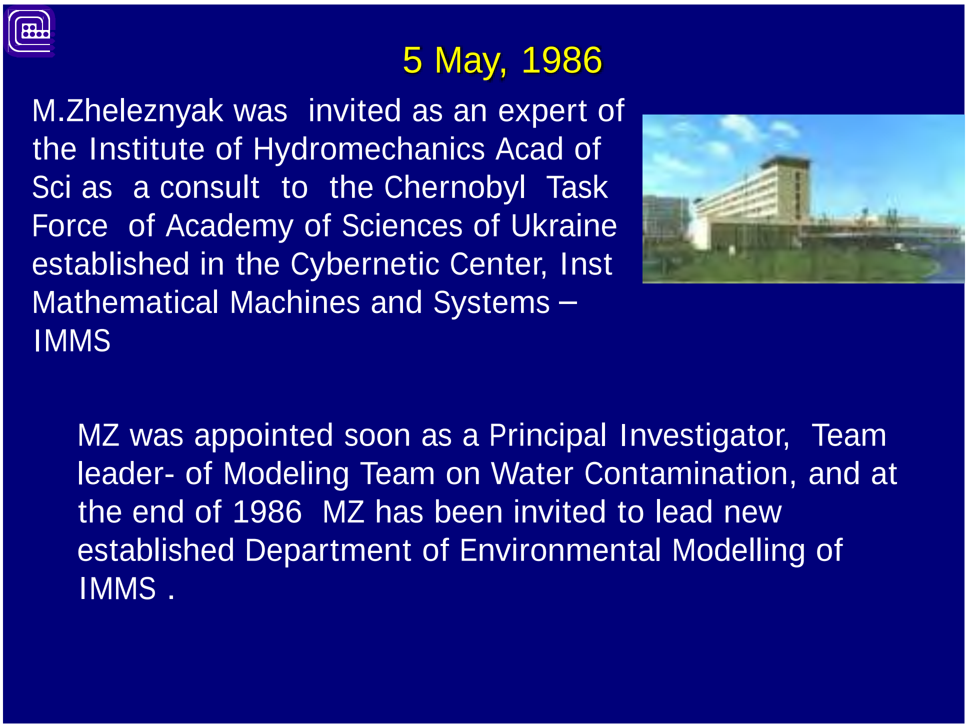


Hello, everybody. I want to thank Mr. Furukawa [ph] and Mr. Onda [ph] for invitation to be here and to visit the very interesting place yesterday on the laboratory site in Fukushima area. Of course, for me, for person who was involved in the study of water problem of Chernobyl since May 1986, it's very interesting to start cooperation with you who now have a similar problem here in Japan.



For me personally, visitation started in May and to give some similarity between situation that could be related to in our country now in Japan, because after Chernobyl accident people could never before study radionuclide transport plan to study radioactivity. Of course, people who have before experience of the studies of water problem.

For me, first of all, it was about how to [Unclear] aquatic contamination problem for Ukraine. You see Kiev is downstream of Chernobyl Nuclear Power Plant located in the tributary of the Pripyat River and distance approximately 120 kilometers from Kiev to Chernobyl. Between Chernobyl and Kiev, it's a deep reservoir with a volume [Unclear] and, therefore, in the first week after the accident when [Unclear] discussion practically stopped after 10 days, people in the government, people who were responsible for the information of disaster looked on the water contamination as one of the major environmental problems in Ukraine.



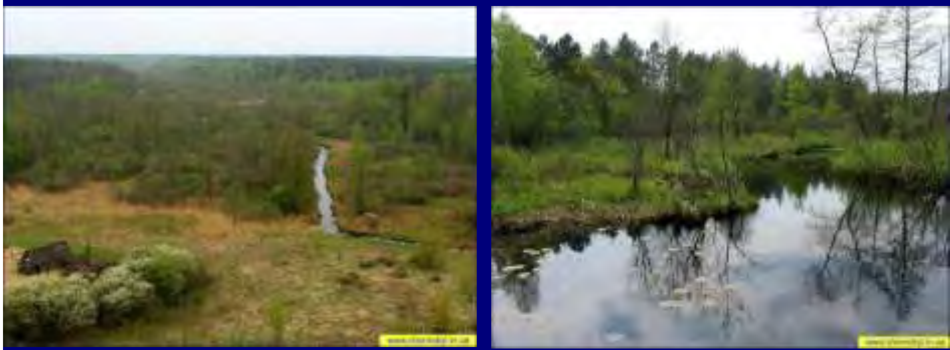
A special group was created in Academy of Science Taskforce for the forecasting consequences of this contamination and [Unclear] hydrological engineer [Unclear] a Master degree, it might be that he was in computational fluid mechanics and this combination of fluid in hydrology and fluid mechanics was required in this moment to develop model of contamination transfer in the water system because, of course, it has capacity to simulate water movement and contamination and immediately from May 1986, we started to study specific radionuclide transfer.

At the end of the same year, a special department was established in the Cybernetic Center, Institute of Mathematical Machines & Systems. I was invited to the hydrology department and I'm in this position for 25 years. Other group departments [Technical Difficulty] and we are working in the different applications, you will see, of the aquatic science and environmental modeling.

May, 1986- mid of 90th

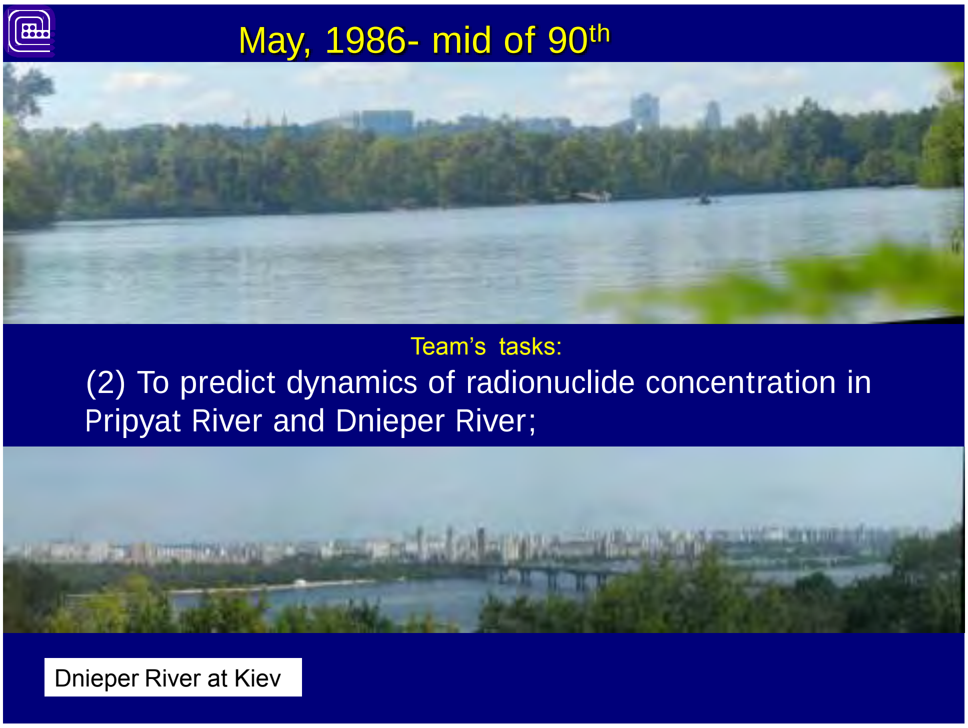
Team's tasks:

(1) To develop modeling system for the simulation of the radionuclide transport in surface water systems surrounding Chernobyl NPP;



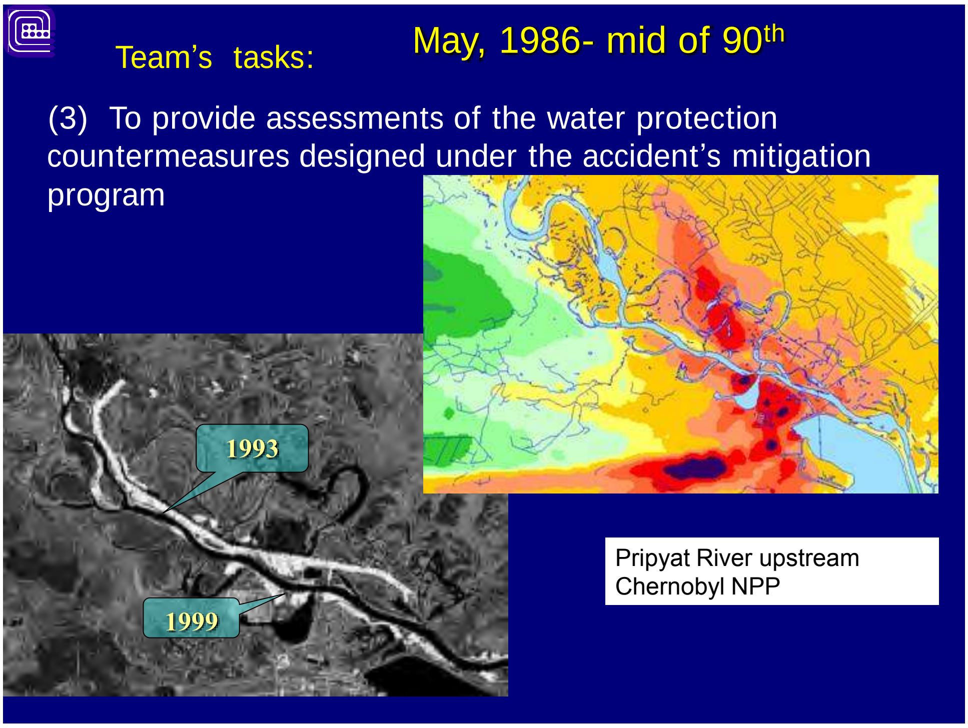
Ilya River – the tributary of the Pripyat River in Chernobyl Exclusion Zone

What tasks – we see what challenges we faced from May 1986? These were the three main tasks. The first task was to develop modeling system to simulate radionuclide transport in the vicinity of Chernobyl Nuclear Power Plant. You can see this picture how it looks, the landscape around Chernobyl. The similarity with Fukushima site of the scene but there's also you see forest, but the big difference that it's plain, it's very plain area without any use and you have mountains but the character of the soil in many places and kinds of the landscape and it's similar in forest area.



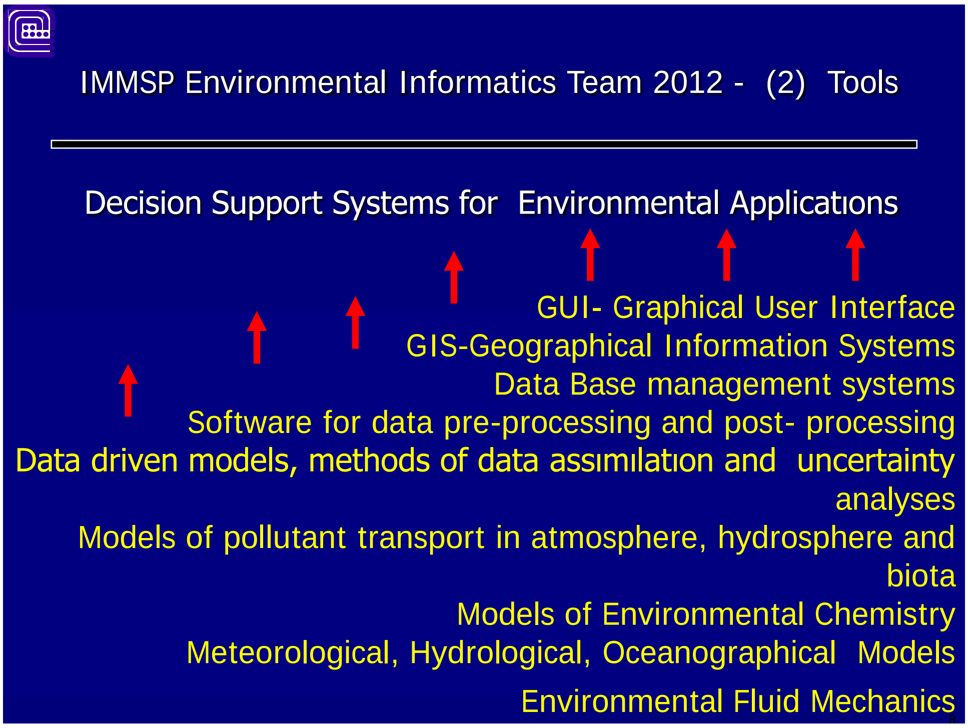
But as you go downstream this watershed around Chernobyl Nuclear Power Plant is the big city Kiev, at 3 million population and this Dnieper River with water discharge is something up to 20,000 cubic liters per second and the average discharge is around 1000 cubic liters per second. The question of contamination in the Dnieper River and downstream up to the Black Sea for Ukraine is also very important.

The second task is what's the prediction for Kiev and downstream.



The third task was the [Unclear] of study of monitoring data and modeling data to make recommendation how to protect water system from contamination. Now, you see zone 2, the territory of Chernobyl Nuclear Power Plant. The power plant is here. This is the place of the nuclear power plant and they also evaluated to monitor as a part of this nuclear plant contamination. You see this white line is construction of the dikes in 1993, 1999. It was constructed as a result of our modeling [Unclear] efficiency of the countermeasures. This task forecasted and the decision support for some technical countermeasures.

These were many countermeasures proposal but some of them are, as you see, analyzed. Of course, such activity could be as combination of monitoring and modeling data. If modeling data, my team was responsible. For monitoring, it's Hydrometeorological Institute in Kiev; a team of my present colleagues came out with this approach. Now, also we have a special center in vicinity of nuclear power plant in Chernobyl, like I said, they continue to provide monitoring in this area, I will say, a little bit further.

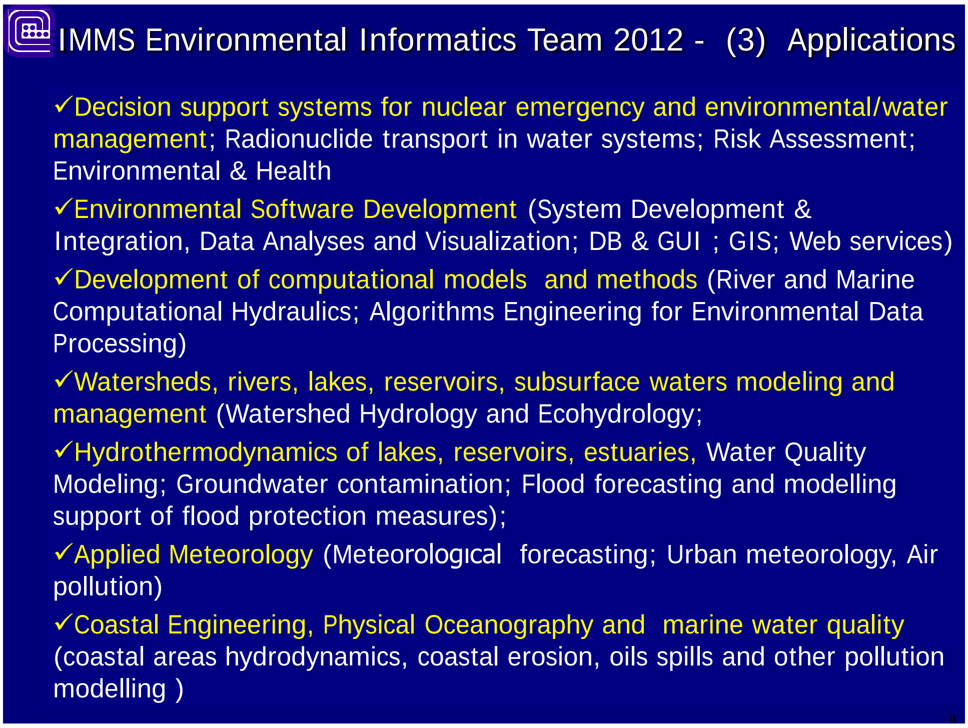


Our task was to develop a modeling tool to predict radionuclide transport in water. The structure that I demonstrated here, it was established year by year but now to develop decision support system for environmental modeling, we have a professional expert in the different fields of environmental science. As I told to you, we should describe movement of the fluid and to [Unclear] fluid with the sediments and, therefore, we have professionals who have graduated from Fluid Mechanics Department and specialized in Environmental Fluid Mechanics.

We have specialists in meteorology and hydrology, oceanography because we also apply our models for Black Sea, of course very important in Environmental Chemistry, because the process of physical-chemical transformation of radionuclides also should be taken into account. Also in aquatic biota, I involved both the processes of contamination and dust formation, fish contamination and to model this, you also should have a professional and developed model of pollutant transport as in atmosphere, hydrosphere, also in biota.

We apply as technological models and as also models that are based on data-driven methods such as artificial rain network, multi-user operation, and also the methods of data assimilation during the modeling. We developed the software system because some of our software now installed in the operational center of our hydrometeorology service and we are part of the European system for prediction of radionuclide transport, so we should have also professionals in this area and also it's necessary to prioritize the GIS data, Geographical Information System, and develop graphical user interface for potential users.

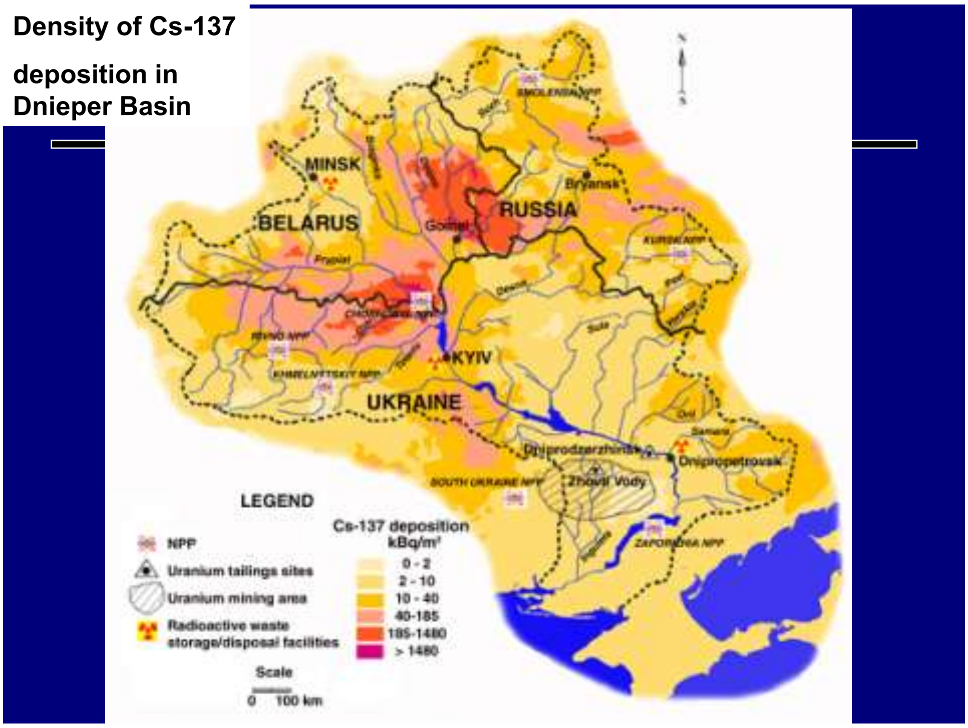
Today our team is, as I said, two departments are working together; it's approximately 50% that represented all these directions of objective meeting.



When we say about our applications from 1986 to middle of 90s, our main application was Chernobyl and the European system for simulation of radionuclide transport.

But from the mid of the 90s, we didn't see prior activity and now working in all these listed here applications, including Applied Meteorology, we're on meteorological forecasting model, WRF, in our department for calculating rate and applying different tasks. We can have many projects in coastal engineering. I've taken my simulation of [Unclear] in the coastal area sediment transport for coastal and it would be very useful to simulate radionuclide transport in the coastal areas.

Coastal floods, we're now working in the flood forecasting and the climate change, impact from the flood and coastal flooding warning and so on.



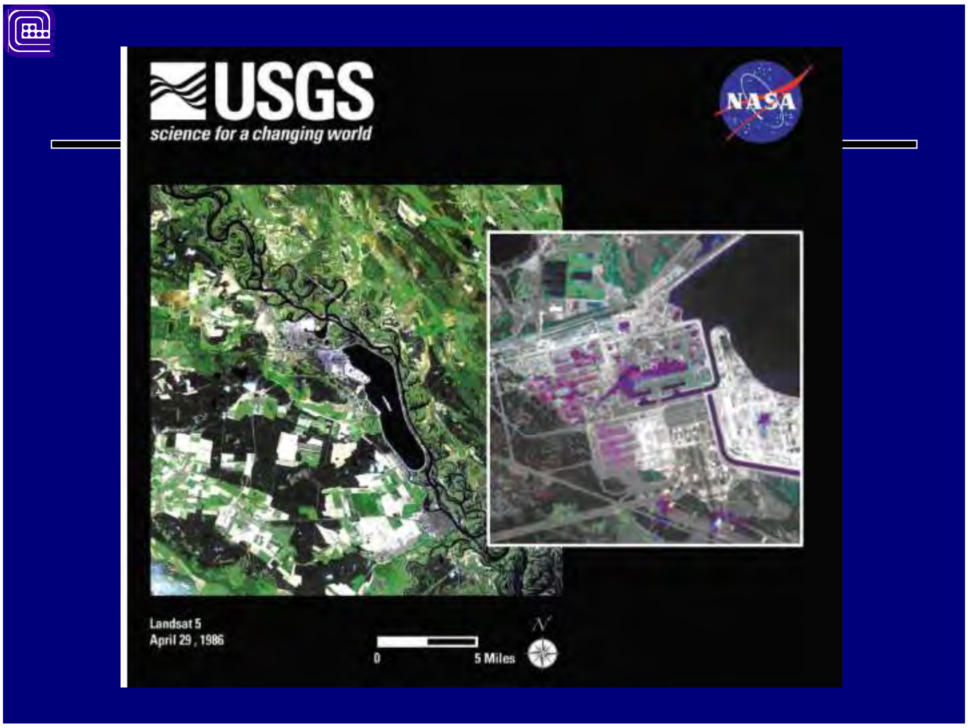
Now I will say down to the task, and how we tackle it. Now you see a more detailed map of the 3 zone contamination after the accident. If you look on this map, this black line is the border between the countries. In 1986, it was one country Soviet Union, as you know. But since 1991, we're divided into Ukraine, Belarus, and Russia. You see that this contamination – mild contamination here around the [Unclear] but also contamination in part of the Russia, in the [Unclear] Russia. Also, in this map you can see another source of potential radioactive contamination.

In Ukraine, Chernobyl Nuclear Power Plant was shut down. We have four units in Chernobyl. One was destroyed and second was damaged during the accident. But two another units, two reactors, number one and number two and at the same time that's number four that was exploded, continued to work and produce energy up to year 2000, but from 2000, Chernobyl Nuclear Plant gets shut down, but we have another nuclear power plant, [Unclear], another kind of reactor, BWR. Now new reactors are constructed here and here, and the South Ukrainian Nuclear Power Plant and the largest in Europe, Zaporizhia Nuclear Power Plant, six reactors.

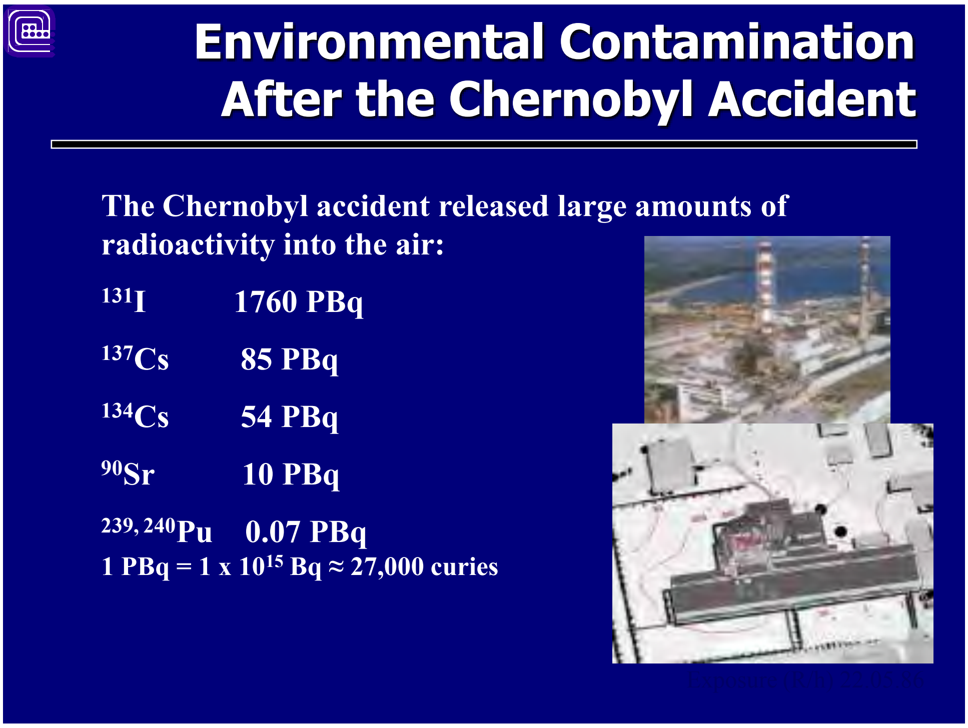
Of course as here in Japan, it was a big shock after the accident and this was happened to shut down, in general, nuclear power production in Ukraine, in

Soviet Union, but it was Ukraine at large. But, first of all, it was Soviet Union, who was not very sensitive to the public opinion, but after countries started to be independent, started to declare that economically it wasn't possible to shut down the nuclear power plant because Ukraine has not – they own big grasp on oil sources particularly from Russia and it came out practically as a real alternative to continue develop nuclear power production.

Plus what we have in Ukraine, we have the Ukraine uranium mining and uranium processing plants. It was working through the time and there's no pollution around there. We started from Chernobyl, but now we are involved also in the risk assessment on all these objectives. Also in the Dnieper Basin it's two Russian Nuclear Power Plants, in Smolensk and in Kursk.

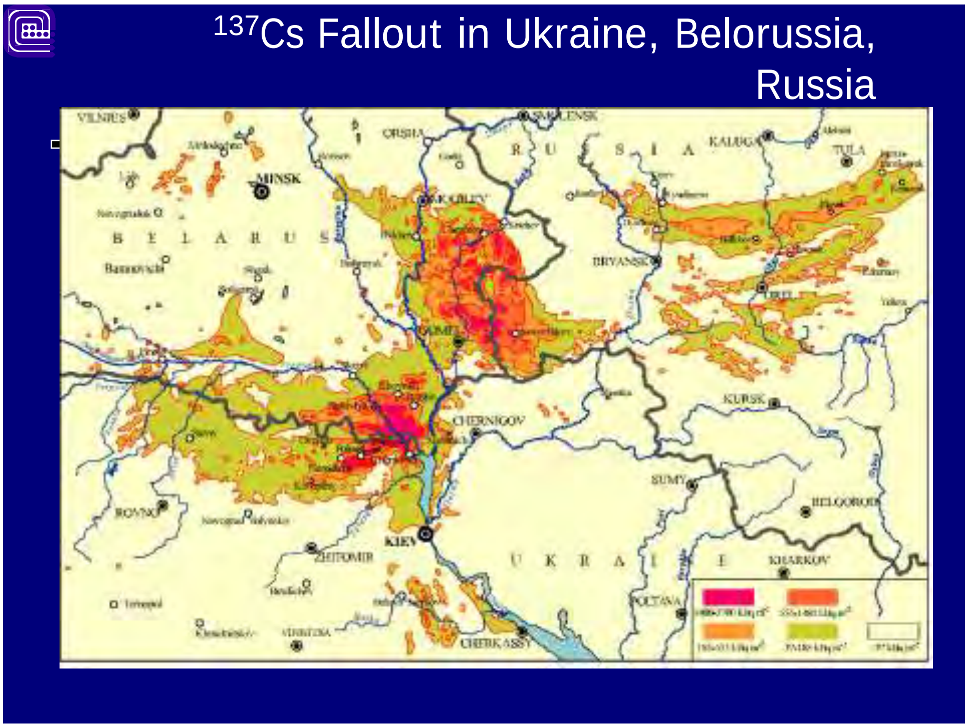


Now it's from this USGS satellite, how the territory looks before accident. This picture was taken during the accident where this color is temperature. The picture demonstrates a part of the flood that destroyed the reactor. It was explosion of the reactor and it was open and some of the floods around this territory. You can see this picture.



It was fully destroyed nuclear reactor and you see the water here in the cooling pond and floodplain and later I will say about it. You see how this contamination was around the [Unclear] reactor. You see that the major radionuclide release was iodine and there it is.

But also it was two kinds of cesium, 137 and 134. But it was a big amount, but most are significant because short period of the degree and also strontium and a significant amount of plutonium. Therefore, for us in our study of environmental pollution, the most important was because iodine very significantly was decreased, so first the most important was cesium, strontium, and a little bit plutonium, but plutonium wasn't dispersed in the big areas, only concentrated near nuclear power plant, because it's mainly in this fuel particle, because part of the fuel was particles was dispersed here in the cooling pond and the surrounding territory of the site that is nearby.



I'll return to this map. Also, we must say that Kiev is a very lucky city. Because you see this direction of this fallout, these different directions resulted that it was one explosion, but after that it continued up to 10 days. The fire in reactor continued dispersion of radioactivity and aerosol and the wind changed direction. Depending on the direction of the wind, you see how was the formation of the fallout. I should recall this time, 1986. It was a quite different country. It's a tragedy it was not a tale. It was a real organization and all information about the Chernobyl accident was secret and all data was secret.

Here in Ukraine, fresh information about the accident that's only 112 kilometers from Kiev, we received from the Voice of America and BBC and other foreign radio stations. It was officially prohibited, but you could shut down or get confirmation, because the stories that first alarmed about this accident was started in Sweden. One was the Swedish nuclear power plant. Each nuclear power plant, they have a system. They controlled people who're working in the nuclear power plant. When they finished their working day, they should come through the special detector.

On the 27th of April, people who were working at this nuclear power plant, when they tried to come through from the nuclear power plant, they were stopped because it was demonstration of high level of radioactivity on them. First it was ideal in some [Unclear] in this nuclear power plant, but later they started to reconstruct the source, open the direction of [Unclear] and they constructed the Chernobyl Nuclear Power Plant. Of course it was impossible that they can see it in Kiev, because many people who're working there, they have relatives, but this was mainly on the level of rumors.

Official information was in Kiev, I think, around 27th of April, people who lived in the city here in Pripyat nearby nuclear power plant, 30,000; they were evacuated on 29th of April. But in Kiev in principle, people have [Unclear] in many places, of course we have from Soviet time a good system of civil defense preparing for the nuclear war with the United States and initially here we have [Unclear] and, therefore, people started to confuse them. But after the 30th of April, there was no demonstration of the level of radiation, because all this time, we'll go in only this direction. Only on the 30th of April, it started to change direction, going to Kiev.

At this moment in Kiev, we could detect increasing of radioactivity. But you see that there is a line of the significantly higher level of this fallout stopped practically the northern border of Kiev. Because if you turn this fallout to the south to Kiev, to the southeast, you see that it was potentially that Kiev could be in the high level of radioactivity. We're double lucky.

We're lucky that we do it in the same direction and we're lucky that accident happened in April, not in the beginning of March or in February, because we have snow cover as usual in this period, but snow is melting in the first week of March. If accident happened in winter, in this case, all this radioactivity falls down to the snow. Then after the snow melting, much, much high amount could be washing out to the river but it has not happened.

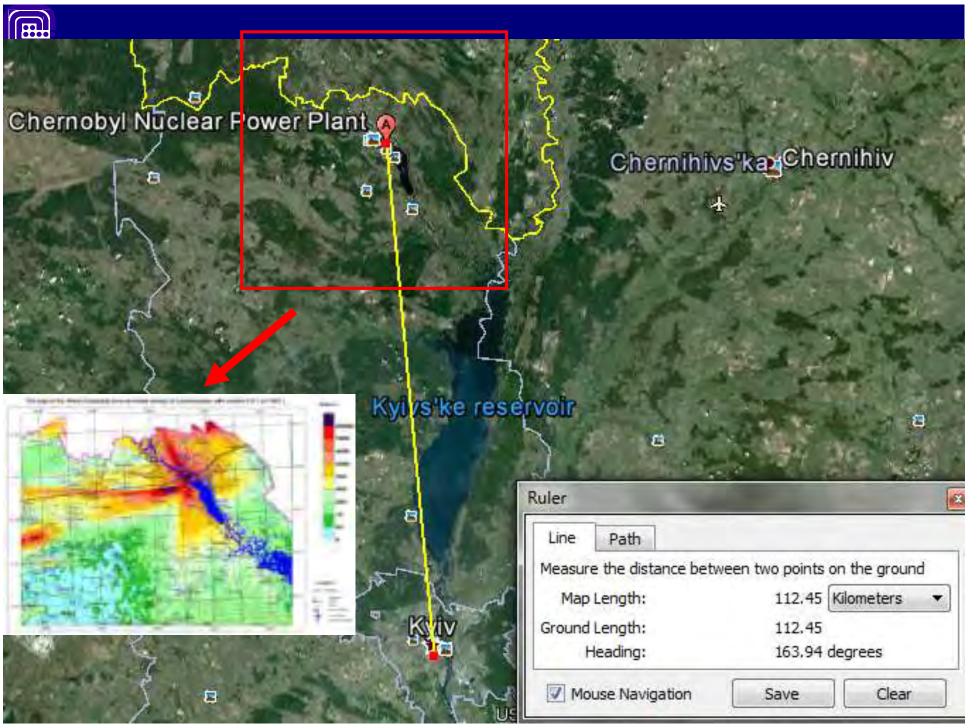
Another few words about the situation, immediately it was put to big resources, many people were sent to work here to do something and it was many ideas from some research institutes how to diminish the danger for Kiev, because everybody was afraid that this contamination could be washed out during the heavy rains and propagate as to Kiev as also to downstream, because population of Ukraine is – now it's 45 million, but at that time it was at 50 million. Maybe half of this population by different manner received water supply from the river, as for the drinking water and as for the irrigation. Before, it was considered a serious measure.

Another site of the Soviet system and this secret situation that you have, we haven't had any possibility to use international knowledge of the problem. Because when we say about the problem of the contamination of water system, about radioactivity, it's not started in Chernobyl. The radioactivity started much early in the end of 40s, beginning of 50s, when Soviet Union and United States developed first nuclear reactor for the weapon, for nuclear bombs. This situation was a bit far from the two river basins in United States, it's Oak Ridge National Lab. They have near the Tennessee River. Watershed was highly contaminated. Uranium nuclear bomb was produced in Los Alamos. It was never any rivers there.

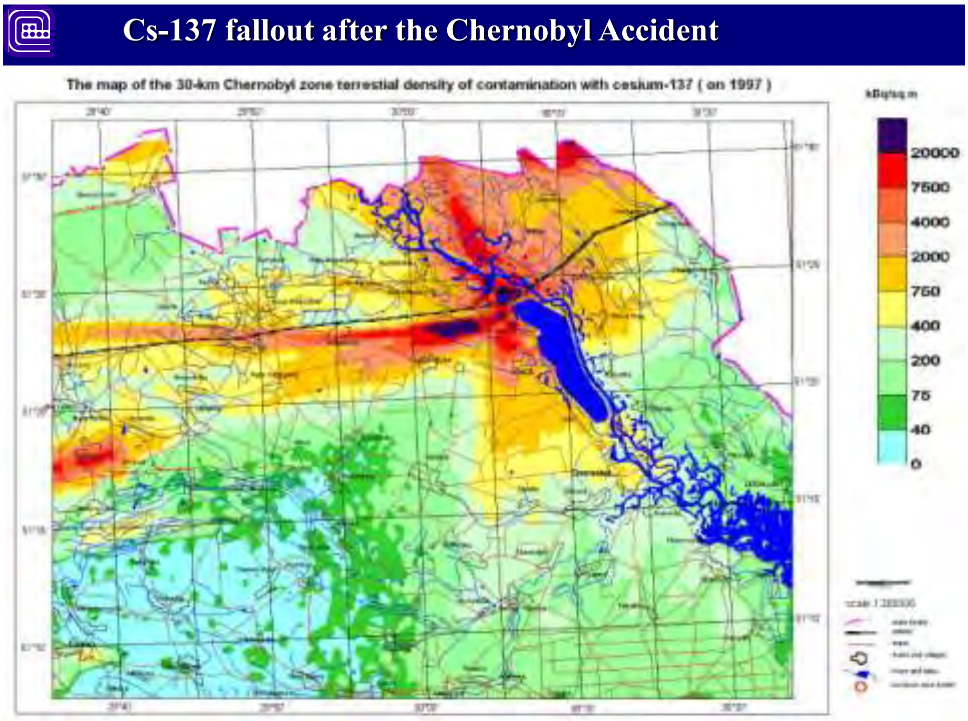
But plutonium reactor was located in Hanford Site, State of Washington, regional but it's now Pacific Northwest Laboratory. This Columbia River in this area was very highly contaminated. Therefore, in principle in this moment who have the largest knowledge about contamination of rivers after the accident, it was Americans who work at Oak Ridge National Laboratory and Pacific Northwest Laboratory. One was there now Yasuo Onishi. He actually worked here in Japan as a representative at Department of Energy. In Soviet Union, also it was contaminated river in the Ural part in Techa River near Mayak Enterprise.

But we could not communicate of course with American on any other of the societies though it was a secret situation, but what we can do we could read papers. Immediately we started – because for me, I came, as I told you, to this business from river hydraulic from hydrology. I know how to simulate at this moment [Unclear] for me how to simulate water movement and sediment transport movement. But they came up with the idea in the beginning about radionuclide transport and I started to look on the publication. I've found just four publications. We also have initially three-phase modeling system for this.

In Soviet Union, this study for Mayak, we have two problems. First of all due to this secret system in the country, we could not find this report at station level. The second problem is that in Soviet Union it was a general statement that large-scale accident in Soviet reactors is impossible. If accident is impossible, you haven’t any reason to study consequences for large accident. Therefore, they never provided some – before the accident, business activity, so we should practically start from the zero and we have a task to the period of autumn, period of the significant rain prepared first modeling system to simulate radionuclide transport in aquatic system, so we started.

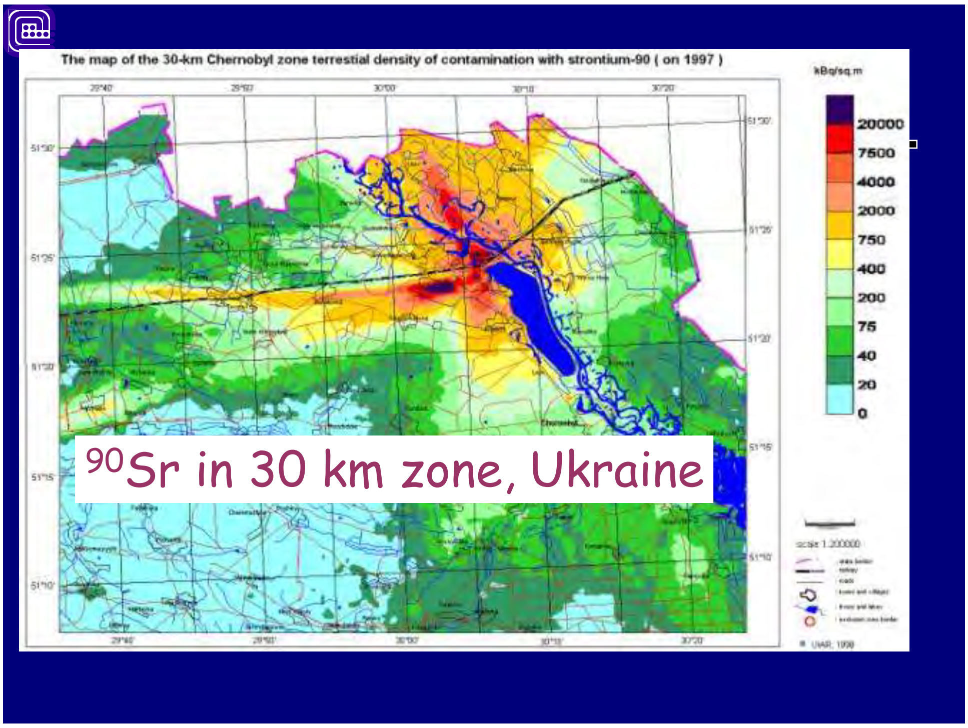


A few illustrations, they are not from Google Maps, I'm going to show you the distance of Chernobyl, the line was 120 kilometers. This map will say it in more detail.



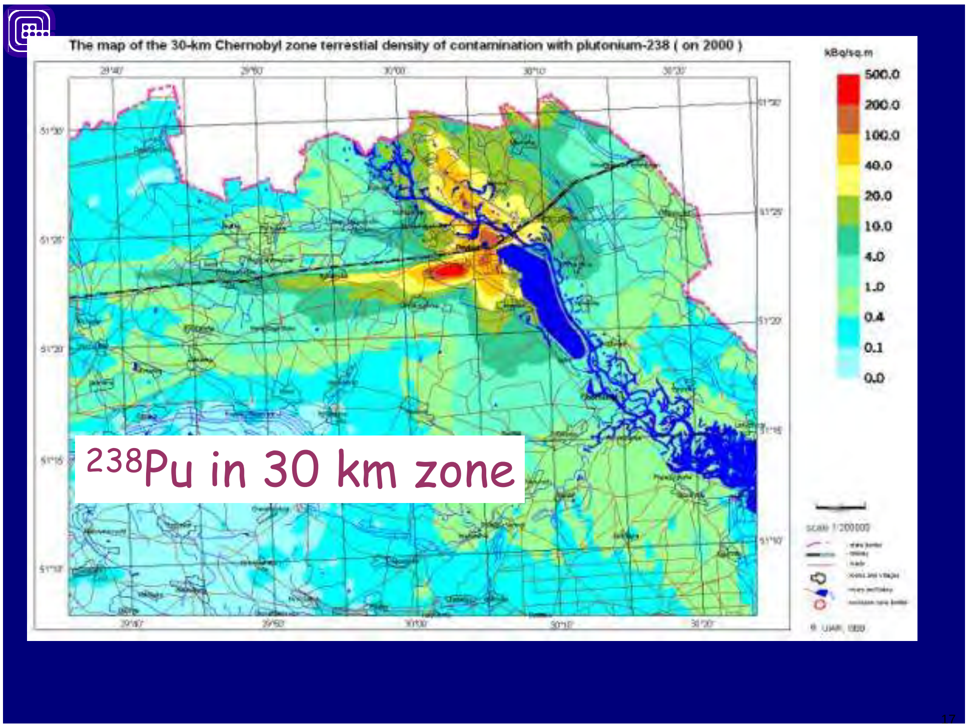
Now, we can zoom to the territory of Chernobyl Nuclear Power Plant. You see the delta of the Pripyat River, and here the Kiev Reservoir. This big water body is cooling pond. It's perhaps at 7 kilometers. We also read about this. Here you see a map of contamination of cesium.

We have this territory with very high contaminated by strontium and cesium. Nobody knows what happened if it will be flooded. Rich amount of radioactivity will be washed out downstream. It should be well estimated. First and second, try to develop prediction system and make recommendation how to prevent this.



They will show you a similar map of contamination of strontium and a similar map of contamination of plutonium. In principle, plutonium is a sign of the fuel from reactor. You see this spot of fuel was well known, Red Forest is a forest area here.

But here was such a high level of radioactivity that [Unclear] died. From Green, they started to be red. What is that is also important to say. Here in this place is city. Everybody knows Chernobyl, the name of the city Chernobyl, but in reality, more close to nuclear power plant the city built it, a city where 30,000 people were living in the city, 30,000 people. It was tough for the main part of the Chernobyl Nuclear Power Plant. You see that contamination was very high. Now in my department, several people are working.



My secretary chaired during the accident, but she remembered how she was standing in the balcony of the house and saw fire from the reactor, because it's very close, it's something like 1 kilometer from reactor. But when the people were evacuated on 29th of April, nobody knows at this moment that they were mapped for contamination and they were evacuated by this road exactly on this day and even they stopped in some places here to change goods, but this place was also very contaminated. That is the story with this spot in the Red Forest. Forest was gutted and buried in the same place, but it includes very much amount of plutonium.

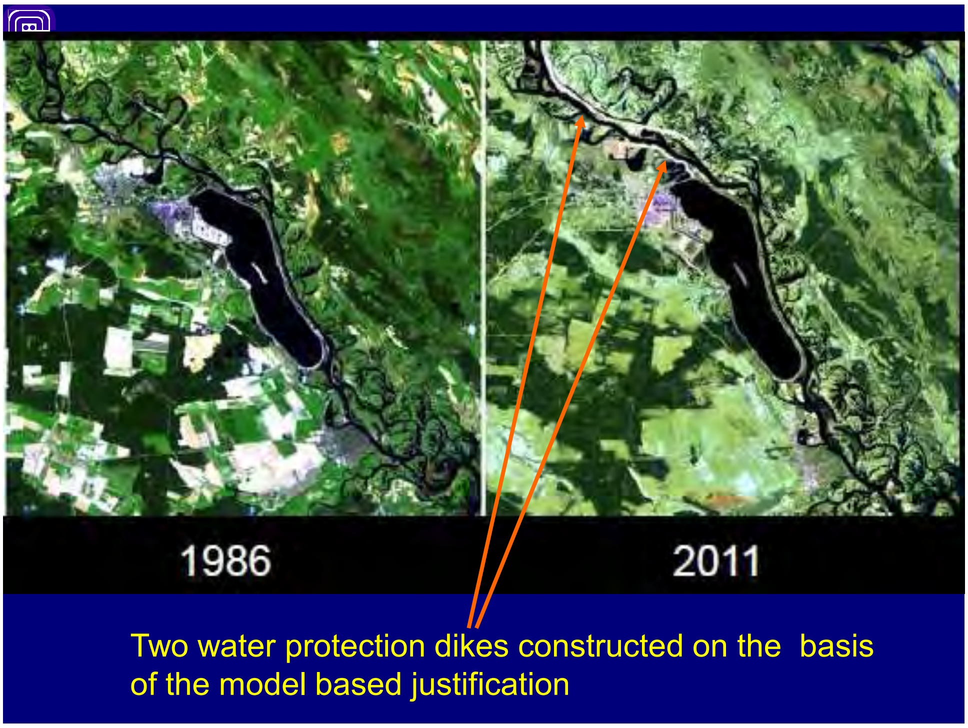
Plutonium in general not actively propagated in soil, because this was very high distribution confusion and immediately uptake by the soil. In principle, in the water even and because of affinity practically impossible to find significant amount of plutonium in water. But what's interesting that in the forest together with cellulose, there is wood. [Unclear]. They promote migration of plutonium. For now, these places where this formal forest is buried, we've now started increasing migration of plutonium to the burnt wood.

Another interesting story, but also a demonstration of the both time of Soviet Union, American competition was that in 1990, press conference where Soviet

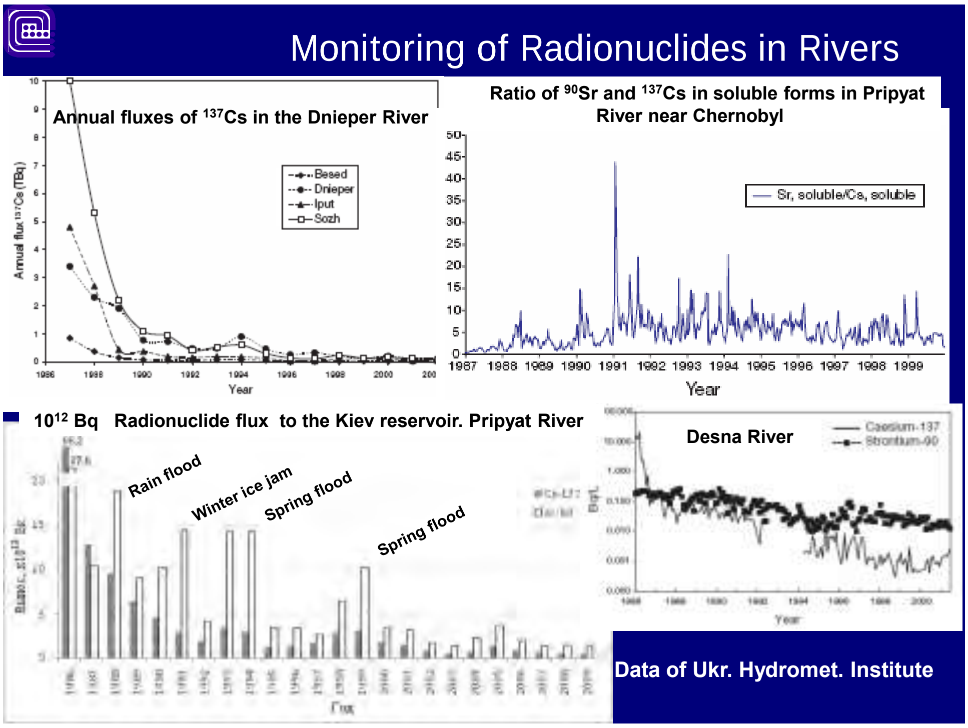
Environmental Physics met Americans. It was a conference about three-module accidents about Kyshtym in Ural, Windscale in United Kingdom and Chernobyl. Americans tell us that they haven't official information about the amount of radioactivities that was released from nuclear power plant, but they provide such estimate.

They found in [Unclear] United States forest with oak similar to the oak in Chernobyl. From the helicopters, they put in different part of this forest, cesium to the trees. At the same time, they made satellite picture to see how color changed independent from the amount of cesium that was the fallout of this forest. Basically, they estimated which minimum amount of cesium was the fallout in Chernobyl zone. When they opened their results, it was really close to the real fallout that's given here.

But now you're done of those historical references about our problem. This territory was radioactivated, forest was gutted, most contaminated territory here was – upper part of the soil also was removed. But for us, it's important territory here near the river, here is the flood plain. This territory is approximately 10 kilometers in length and up to 2 kilometers in width. This territory could be flooded by floods with a frequency of coolants one time for a year as hydrological people say it's floods of 25% probability of [Unclear].



As I told at the result, you see the difference between the pictures of 1986, you see here is the nuclear power plant itself, the city of Pripyat evacuated I told you about this. Now, it's empty. You see these two dikes that were constructed in 1993.



First of all, I will say a few words about monitoring. Before you construct a model, you should, first of all, have good information about situation of the river system. Monitoring started in 1986. In all these rivers, it was in the contamination zone.

Now what we know after the years after that, first of all, the fluxes of cesium, concentration of cesium in the rivers significantly diminished during the first 3 years after that, but the situation is a little bit different for cesium and for strontium. Of course for you now, strontium is not proven, but it's interesting to compare that to the premise what is even for this difference. You see that, for example, Desna River that confluences river near Kiev. You see that the concentration of strontium is on a rating scale practically on the same layer from 1986 to 2010.

But as for the cesium at the same time, you see diminishing curve up to three level of magnitude, even up to four orders of magnitude, a similar situation to the inflow from Pripyat River to Kiev reservoir. We see this black line. Black line is cesium annually-relevant concentration. You see how it decreased during the first year. But if you look at this white column it's strontium. We shared that even after some years after the accident, even after say a few years, you put very sharp increasing of the concentration. This sharp increasing in concentration is a result of the flux. Because during the flux, first of all floodplain is flooded and this is the floodplain near Chernobyl and other territories.

It's washing out sediment – strontium is propagated mainly in solute, only in very small amount of strontium is transported for sediment, particularly this or strontium is propagated in sediment. When a larger territory is flooded, contamination from this territory is dissolved and come to the river. If you see this event in the big rain flood, it was winter [Unclear], spring floods with snow melting. Each stage flood was increasing the level of contamination. But we were lucky that last practically from 1999, we haven't any large floods. I'll a little bit later come to this.

TABLE 4.10. EXCHANGEABLE FORMS OF CAESIUM-137 IN SOILS OF THE CHERNOBYL EXCLUSION ZONE

Type of soil	Sector (distance from nuclear power plant)	Per cent exchangeable form
Automorphic	Northern (2–15 km)	6–15
Automorphic	Northern (15–50 km)	15–30
Hydromorphic	Northern (2–15 km)	2–9
Hydromorphic	Northern (15–50 km)	2–28
Peat–bog soil	Northern (15–50 km)	6–9
Podzol–sandy soil	Northern (3–4 km)	2–13
Peat–podzol soil	Western (3–4 km)	1–10
Podzol–sandy soil	Western (4–5 km)	3–6

From IAEA Dnieper project TechDoc # 260, 2006

When we try to answer on these both questions, and this answer should be specific of cesium should be taken into account in mathematical modeling, because your model should represent various situations.

What I show you today is all this monitoring data. Of course we haven't in 1986, now you have a situation where you have only 1-1/2 year after that, but what was important and our physical chemicals found that cesium that is dispersed in this area, not all cesium could be diluted. It's fixation of the cesium in the soil matrix. As a result, inaccessible form from different places from 1% to 15%, 30% of cesium, which is a very high amount. Only small amount of cesium could be diluted by the rain and washing out from the soil.

What's most important is they do it as a physical chemical fixation processes; high absorption of the cesium, is also a possibility, the percentage of the water exchangeable form diminished drastically from year to year. In that situation if you have approximately 110% of cesium water exchangeable and during the rain or snow melting, this water exchangeable cesium is washing out from the soil and comes to the river. After sometime, you have less and less amount of exchangeable cesium in the water. As a result, it's diminishing of the concentration in the water.

But for strontium, another story, because strontium in our case in Ukraine, in Chernobyl was connected with four particles, because I'll tell you that was – we say four particles like fuel particles because if you take near Chernobyl Nuclear Power Plant, same type of soil, put the soil and even put the photographic fume above it. After sometime you will see spots, more spots the dispersed fuel from the reactor.

These small particles from reactor after sometime, they started to be destroyed and released more strontium. Therefore, we have two different kinds of the processes. If cesium is continuing fixation of cesium on the soil and diminishing of the amount of water exchangeable form, for strontium it's increasing of water exchangeable form, do it as a destruction of the fuel particles. Therefore, we have [Unclear] different picture for these two radioactive materials.

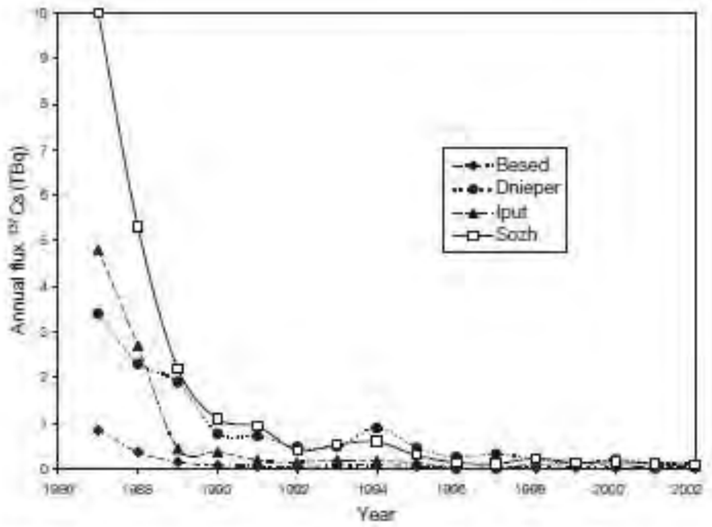


FIG. 4.12. Annual fluxes of ^{137}Cs in the Dnieper River and its tributaries from the far zone of radioactive fallout [4.25].

Also, I'm going to tell you on this picture about diminishing of this cesium for Dnieper River and now situation in Pripyat River, the same situation as for Desna.

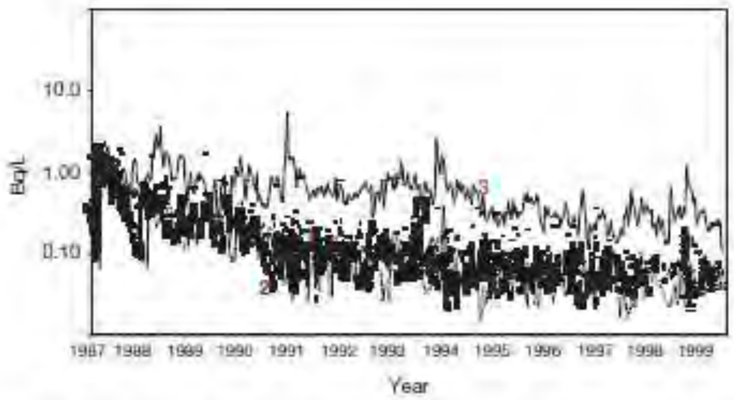
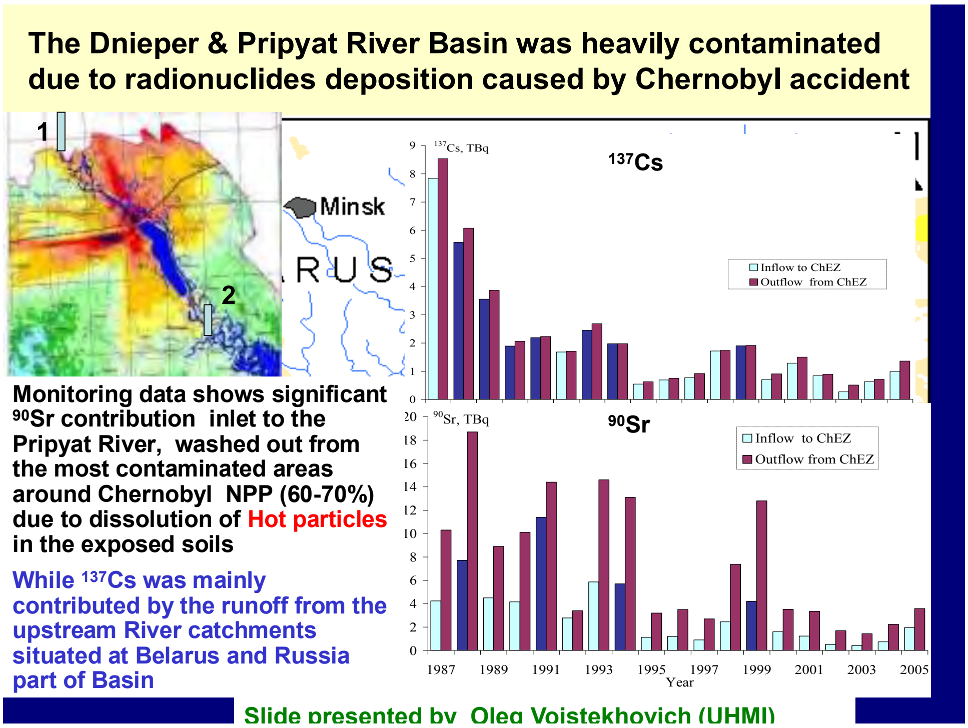


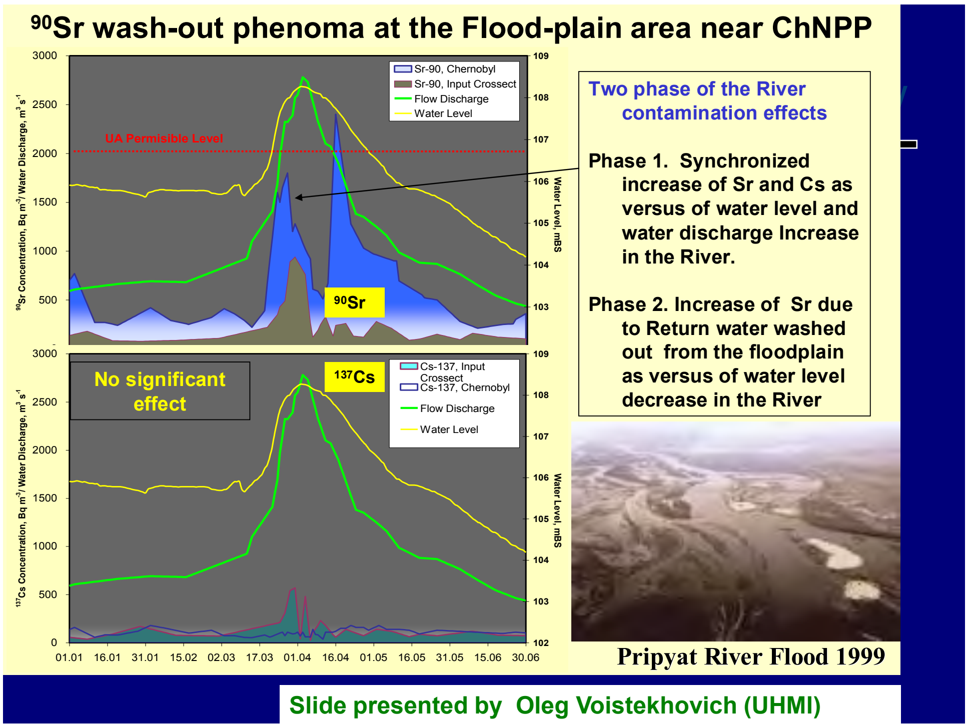
FIG. 4.18. Radionuclide concentration (10 day averages) in the Pripyat River. 1: ^{137}Cs, dissolved; 2: ^{137}Cs, particulate phase; 3: ^{90}Sr.

From IAEA TechDoc 1230

It is practically at the same level of magnitude for strontium for 15 years. Diminishing of the concentration in cesium, but in cesium, here the gray line is not a very good picture, but gray means cesium of sediments and black cesium dissolved. Approximately, half of cesium is transported in sediments and half in solute, in Pripyat in this specific situation. But you also see that we have diminishing of the level of concentration was in one order of magnitude, but for strontium practically the same.

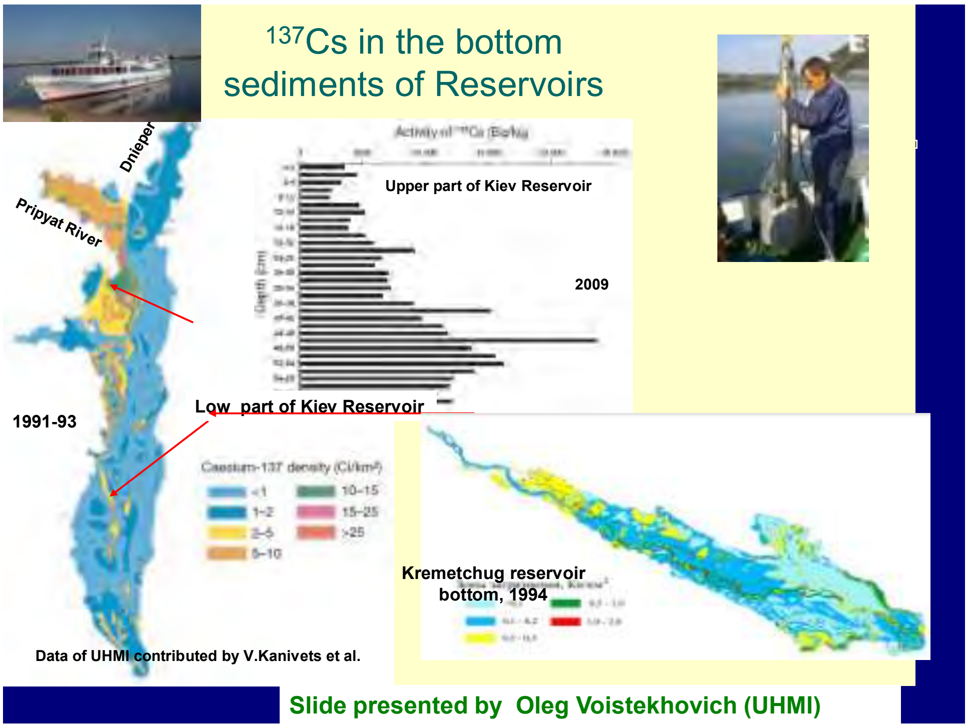


Also interesting situation about control of the contamination, here in the inflow to the Chernobyl zone and here outflow. Upper picture is cesium. We see that after propagation of water in this area around Chernobyl plant, we have increasing of cesium. But in the same time, this wasn't significant. The main part of contamination of cesium goes from the upper part of the basin. But when we look to the strontium, we will see that very significant increasing of strontium contamination here after propagation in this contaminated area, because why we don't know.



Large big flood in 1999, one dike was constructed here. This line is water level at water discharge. This blue line is concentration of strontium.

This line is concentration of cesium. Also, this gray is before coming to this area near floodplain near Chernobyl Power Plant. This is after, very significant [Unclear] in this short distance.



Also cesium was deposited in the bottom sediments of the Kiev reservoir, most significant here in the mouth of the Pripyat River and also propagation in other site.

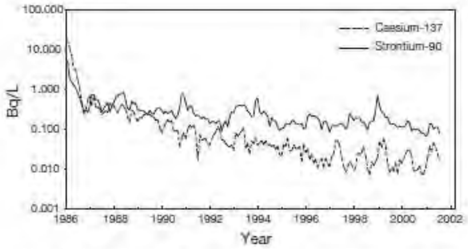


FIG. 4.26. Dynamics of radionuclide concentration in the measuring section of the Kiev hydropower plant, 1986–2001.

From IAEA TechDoc 1230

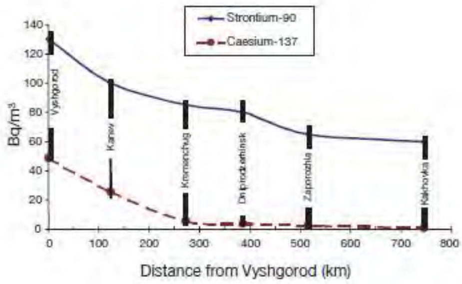
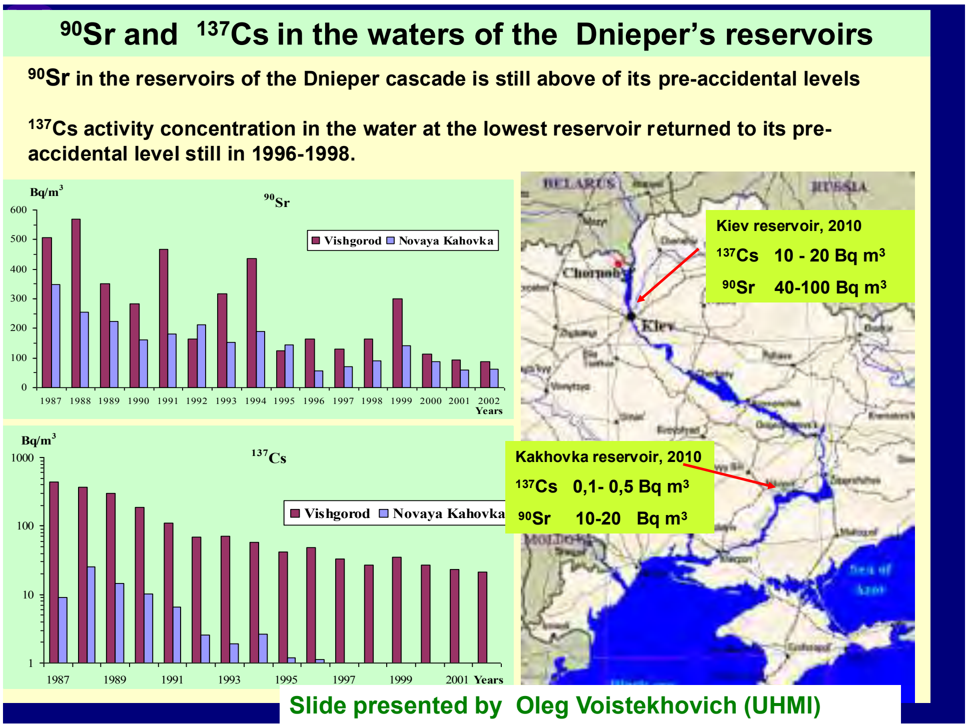


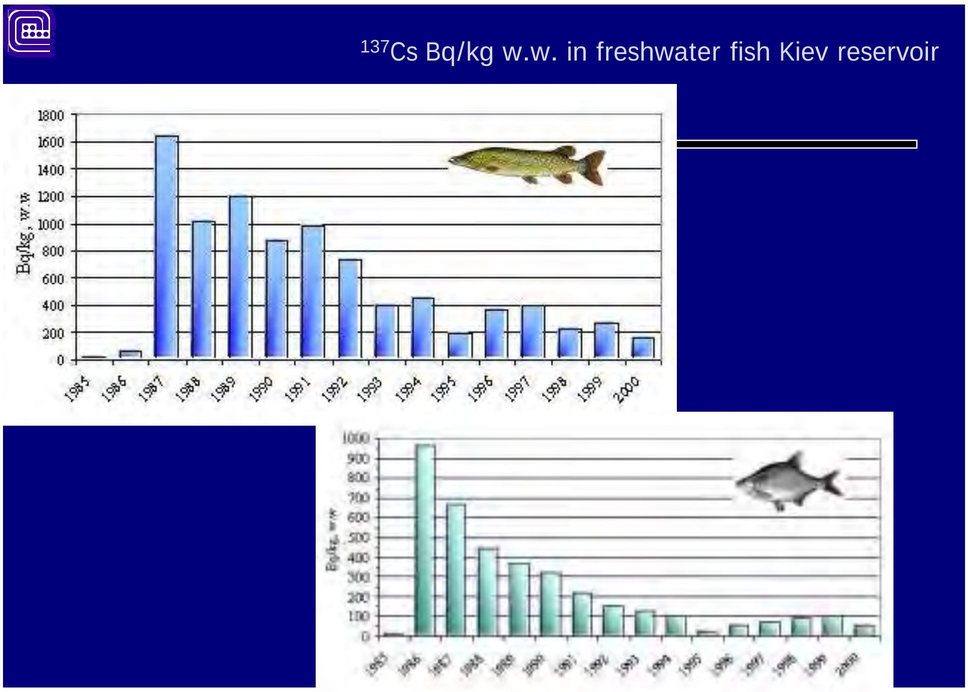
FIG. 4.28. Changes in concentration of ^{137}Cs and ^{90}Sr along the Dnieper River, July 2000.

If you look situation of strontium and cesium near Kiev, the same situation, strontium near the same level all these years, cesium falling down to zero order of magnitude. Next level of the result is how concentration changed with cesium and strontium in year 2000 along the river. We have distance from Kiev along the Dnieper River to Kakhovka Reservoir 750 kilometers.

In this distance, the concentration of strontium due to the dilution and so on only twice diminishing, but few concentration of cesium after 200 kilometers practically concentration of cesium started to be near zero.



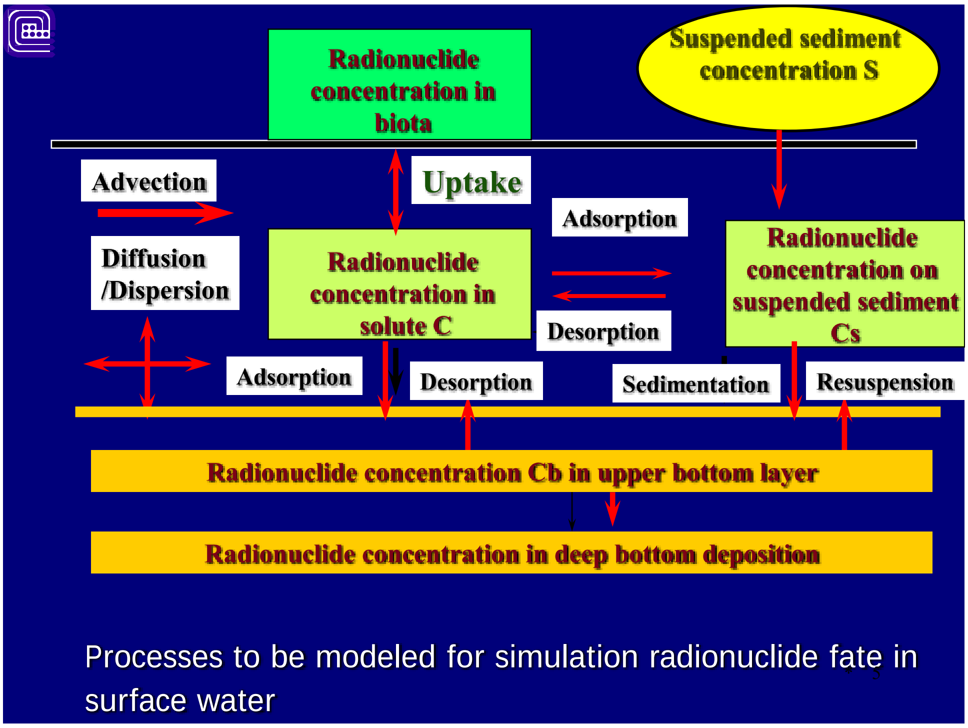
Two questions from all this result. First, why cesium concentration changed very quickly, diminishing after the accident and concentration of strontium continued to be practically the same? Second, why propagating along the reservoirs, concentration of strontium changed a little bit, concentration of cesium changed drastically.



in predatory and non predatory fish species in Kiev reservoir (I.Ryabov et al., 2002)

Also a few words about the fishes, of course you can say about the danger of the water contamination for the population. One of the main reasons is food chain, it's drinking water, but fishermen who eat fish from these water bodies. You see here also the graphs of the cesium contamination of fishes. It's predatory fish, Suka [ph], I don't know what you call it in English, it's in Ukrainian. Of course it's different scale, because predatory fish is more contaminated than non-predatory fish.

You see that diminishing of the concentration also was here because non-predatory fish started to be more clean and that allowed to also started to be more clean predatory fish also.



Now when we come to the description of the models and description of the processes, we could simulate. If we would like to provide physical modeling of some physical phenomenon, in many cases we are working in the field of environmental physics and environmental chemistry, we should simulate all processes and parameterize and these processes. What this process is about?

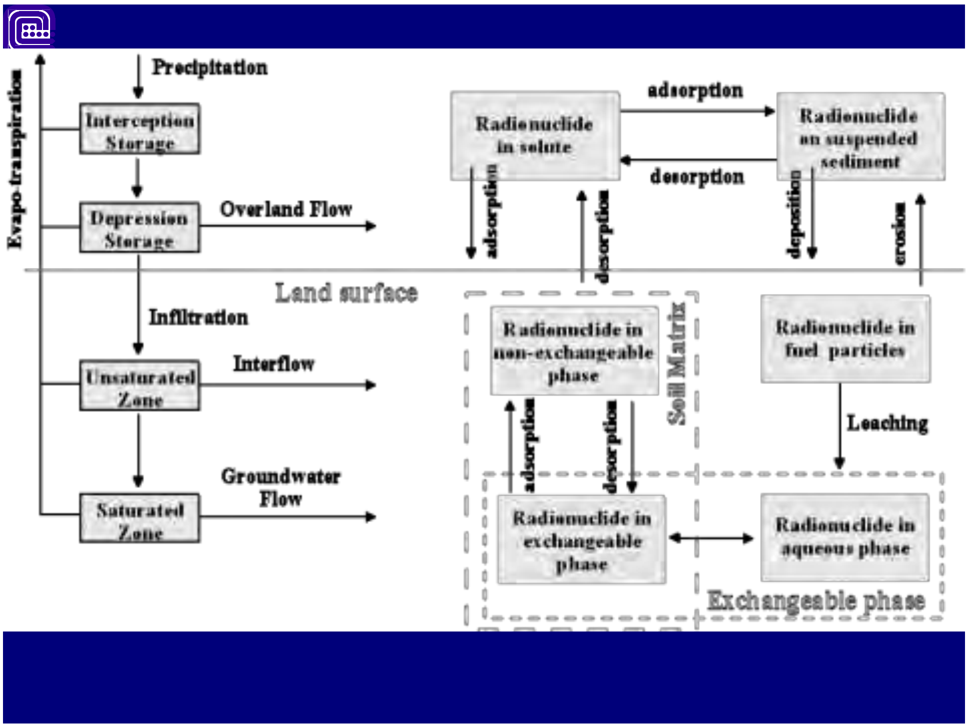
As each contaminant radionuclide is propagated due to the current inflow direction transport and turbulent diffusion dispersion, so river water transport, any kind of contaminant is pushed to the water, raised to the water due to the currents and it could be a turbulent direction that was mixing along the river and the construction of the river, so your model should describe as a direction in the following processes. If radionuclide was a conservative contaminant, it will be quite enough, we could – in this case, only in the river water describe how it's propagated by numerical solution of a direction before the nucleation.

But what is specific of radionuclides similar to the heavy metals that part of it is transported on sediment and in the absorption processes it will [Unclear], so if for example contaminated water come to some part of the river, we have clean sediment and it's suspended there in the water. It's started to be contaminated due to the absorption and desorption. This sediment will be transported to another place and this is another place where slow water currents, it could be sedimentation or in the area of very high level of velocity, it could be a suspension.

Therefore, if you would like to simulate such contaminant as cesium transport to the river system, you should also – could be also simulate currents, turbulent transport and suspended sediment transport. In this case if you know concentration of sediment, you could percolate intensity of this exchange processes. Also we have direct exchange of contamination in solute with the bottom, and do it as an adsorption and desorption and diffusion to the flood water. Sediment could be sedimented or suspended and it also will add something to this. Radionuclide is in upper bottom layer and in deep upper layer because it also takes part, so we should have in our operation three main variables.

This concentration in solute, concentration of suspended sediment, and concentration in a bottom layer and we should have equation that described all these exchanges between all these three variables and only if you have some level of parameterization of these processes, you could pretend that your model you describe the situation and also biota, different kinds of algae, of fishes also are part of the processes, because it’s uptake of contamination by biota.

But in our cases, biota only could be contaminated by solute water or polluted sediment. But in principle, the mass of biota is much, much smaller in order and orders of magnitude in that mass of bottom sediment and, therefore, it could not provide the real direct impact of the balance of this radionuclide in the water system.



It's a simple scheme, but they described all these processes. But later we come to more complicated scheme. I will [Unclear] but a little bit later because we have exchangeable form, slow-exchangeable form. We have river fuel particles significantly and also strontium [Unclear] should be taken into account.

Basic approach for radionuclide transport modelling in surface water

- **The equation of transport of pollutant diluted in surface water could be derived from the mass conservation equation. It can be expressed in terms of the advection-diffusion equation**

$$\frac{\partial C}{\partial t}+\frac{\partial}{\partial x_i}(U_iC)=\frac{\partial}{\partial x_i}(\varepsilon_i\frac{\partial C}{\partial x_i})+\lambda \quad C+\sum_{j=1}^{n} R_j$$

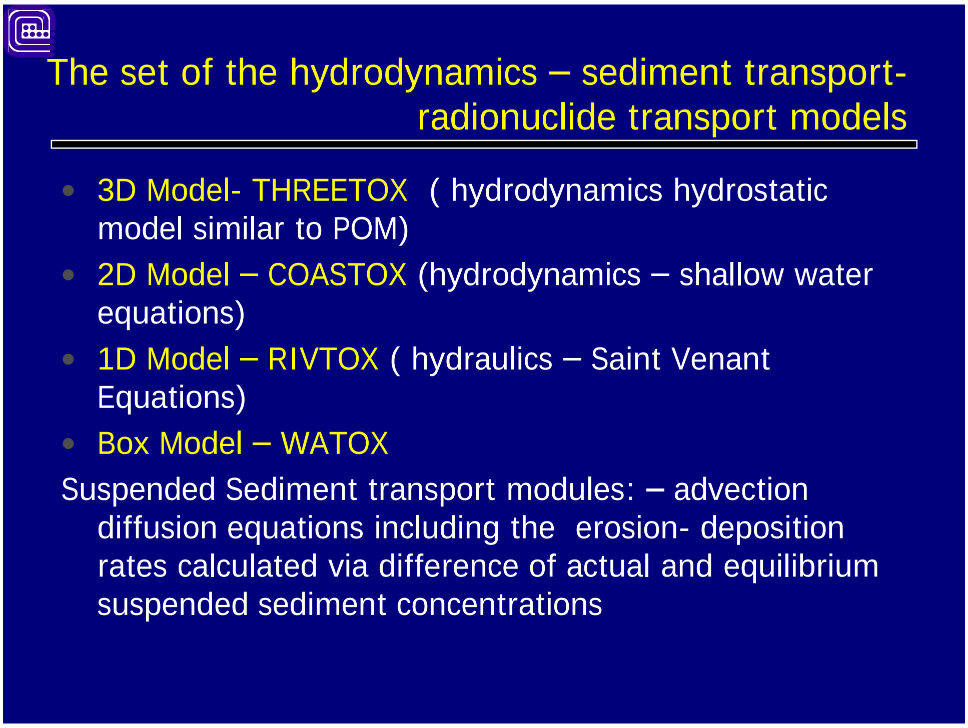
where C = concentration of the diluted contaminant;

U_i (i=1,2,3) -velocity component for x,y,z co-ordinate;

ε_i = diffusion/dispersion coefficient; λ - decay rates for a contaminant;

$\sum_{j=1}^{n} R_j$ = sum of sink and/or source terms (in particular, these terms of the equation describe the exchange of pollutant between solute, suspended sediments and bottom depositions, kinetic transformation rate

But in general, its main equation was the transport of contaminant in any system. Fluid mechanics include the transport by currents advection, turbulent diffusion, and this change seems to have changed the exchange of the contaminant between different parts of the system.



To describe all this and to solve the practical task in detail, we developed not one model, but a system of the model, because we should analyze the event on a very different scale. One of the questions I told you was prediction of contamination for all river systems. This event is up to the Black Sea nearly 900 kilometers. From other side, we should simulate a situation nearby a nuclear power plant itself where it's a scale sometimes 100 meters and it's useful to apply all models for all this task.

Step by step we develop the system of the model that includes part of the river hydraulics and one-dimensional model is based on the seminal equation if somebody has interaction with river hydraulics and basic equation for one-dimensional river hydraulics. One dimensional means that we operate cross-sectionally average concentration of sediment of radionuclides and cross-sectionally average velocity of the river but such kind of the model where you could predict propagation of contamination along the river.

In the case of the cesium, if you also have good parameterization of the exchange of reservoir. Two-dimensional model in play that could be applied to the [Unclear]. We'll hear about this later. Three-dimensional model is necessary in a situation where you have big variability of the [Unclear] in the depth. It's not for the rivers, because in the rivers, all practical tasks could be solved by 1D and 2D application, but first of all for estuary, for coastal, for marine areas where we have a certification by temperature, salinity, and therefore you should apply sediment analysis [ph].

Suspended sediment transport is described in this model by advection diffusion equation, including erosion-deposition rates calculated via difference of actual and equilibrium suspended sediment concentrations, different formula that was being involved.

The set of the hydrodynamics – sediment transport-radionuclide transport models (2)

Radionuclide transport in solute and on suspended sediment modules :

advection diffusion equations including the exchange rates between liquid and solid phases on the basis of adsorption- desorption kinetic equations based on "distribution coefficient" – Kd and exchange rate coefficients parameterizations (similar to Yasuo Onishi's models, TODAM, FETRA, SERATRA)

I told you that when we started to study such approach parameterization of radionuclides, we found many publications, but my choice was at this moment the set of publications of Yasuo Onishi from Battelle Pacific Northwest Laboratory who developed one-dimensional model, FETRA, TODAM, two-dimensional, FETRA is two-dimensional, SERATRA, and all these models were evaluated on the approach, such approach, three components concentration in solute, in suspended sediment, and in the bottom and exchange of contamination and parameterization of exchanges between them.

Basic parameter

Kd i [m3/Kg] -the equilibrium distribution coefficients for i-fraction of suspended sediments.

$$K_d = \frac{equilibrium\ \ concetration\ \ of\ \ radionuclide\ \ on\ \ sediment\ \ [Bq/kg]}{equilibrium\ \ concetration\ \ of\ \ radionuclide\ \ in\ \ solute\ \ [Bq/m^3]}$$

$$= \frac{C^s_{equil}}{C_{equil}}[m^3/kg]$$

A few words about the basic approach for parameterization, when we say about basic parameter, the basic parameter is equilibrium distribution coefficient, Kd, Kd is a ratio of the concentration of radioactivity in sediment [Unclear] the water, because as an example if after Chernobyl accident, I will come to the Dnieper River, take one glass of the water and this glass of the water only 10 to the power of minus four is suspended sediment, because it's plain river, not big metro cities. But after accident in this 10 to the power of minus four, volume of this glass, it was half of cesium.

Then I would like to percolate what is equilibrium coefficient, I should take the ratio of the concentration inside the sediment to concentrations in it.

Characterisation of the key transport, dispersion and exchange processes for radionuclides

Dispersion of dissolved radionuclide by water flow. The process is driven by flow hydraulics. It includes advection and turbulent diffusion.

Dispersion of radionuclides adherent to suspended sediments. The process is driven by the suspended sediment transport in river/reservoir flow.

The rough quantitative estimation of the ratio of flux of radionuclide carried by suspended sediment to horizontal flux of radionuclide in dilute could be provided by the formula

$$\beta = \frac{U\sum_{i=1}^{m} S_i C^{s_i}}{UC} = \sum_{i=1}^{m} K_{d_i} S_i$$

I would like to make a relation between flux of the concentration of sediment and flux concentration in solute and I use this equation of equilibrium coefficient Kd that concentration in solute is equal concentration in sediment – in solute multiplied of Kd,

$$\beta = \frac{U\sum_{i=1}^{m} S_i C^{s_i}}{UC} = \sum_{i=1}^{m} K_{d_i} S_i$$

where m - the number of typical grain size fractions of the suspended sediments by which could be represented suspended sediment fractional distribution (i.e. , clay, silt, sand),

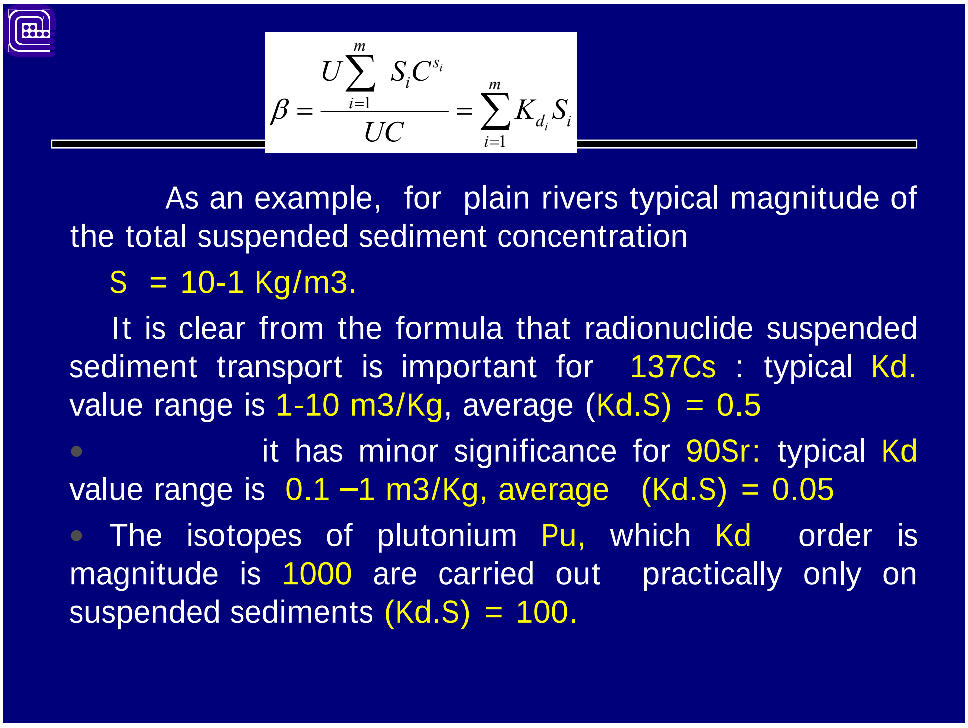
S_i [Kg/m3] - the concentration of i-fraction of suspended sediment in river water;

U **[m/sec] - crossectionaly averaged water flow**

C^{s_i} [Bq/ Kg] radionuclide concentration on i-fraction of suspended sediment in river water;

C [Bq/ m3] radionuclide concentration in solute

I received such relation that amount of radioactivity that transported in the river by sediments is equal to value of Kd multiplied to the concentration of sediment



and as example as I told you that in our plain rivers, concentration of sediment, 10-1 kilogram per cubic meter.

As we know from the very vital issue that typical Kd for cesium, direct Kd is 1-10 meter cubic per kilogram, so we could say that if you multiply one to another, we receive 1 practically. It means that we will have half of the cesium will be propagated in the water but if we have this concentration of sediment, but if in [Unclear] rivers, we will have sediment order of magnitude higher concentration. You receive order of magnitude a high amount of cesium of sediment. Amount of cesium on the sediments depends on two factors, from distribution coefficient and plus from the result from the concentration.

If we provide similar concentration for propagation for strontium, we will receive only 5% of strontium is propagated by sediments. For plutonium, 100, it means that 100 more plutonium is propagated on sediment in water. Therefore, in principle, plutonium in the water is not propagated. It is claimed why this is a situation and this Kd could be applied as for the concentration in the water of the suspended sediment up to the bottom sediment. It's explained why we have such diminution of concentration along the river of cesium, because in principle, only 5% of strontium interacts with sediment and it propagates through the river as a passive contaminant, not attracting [Unclear].

But cesium, first of all, it has direct exchange in the bottom. If contaminated water comes to the clean territory, water started to be more contaminated, but water is more pure. Plus, suspended sediment contaminated could be settled down. Therefore, if your river [Unclear] propagated from the contaminated territory to the clean territory, the more distance, the more amount of sediments will fall down and more cleaner drinkable water at the mouth.

$$\beta = \frac{U\sum_{i=1}^{m} S_i C^{s_i}}{UC} = \sum_{i=1}^{m} K_{d_i} S_i$$

where (cont.)

Kdi [m3/Kg] -the equilibrium distribution coefficients for i-fraction of suspended sediments.

$$K_d = \frac{equilibrium\ \ concetration\ \ of\ \ radionuclide\ \ on\ \ sediment\ \ [Bq/kg]}{equilibrium\ \ concetration\ \ of\ \ radionuclide\ \ in\ \ solute\ \ [Bq/m^3]}$$

$$= \frac{C^s_{equil}}{C_{equil}}[m^3/kg]$$

But it’s a general principle. But we here say about equilibrium concentration, what it means, if I take pure sediment particle and put to the glass with a cesium in solute, it will be in one moment contaminated. It will be sometime for the increasing of contamination of this particle. Therefore, this process is described by the [Unclear]. I have no time.

Moderator

You can, yes.

Deposition/resuspension. This process can accumulate or deplete radionuclides in the bed. It is controlled by hydraulic factors (e.g., river flow, sediment transport), and significantly depend from the typical sediment size fractions (e.g., clay, silt, sand) in the flow.

Diffusion at water-bottom interface. Radionuclide diffusion between insitual water in the bed and overlying water create long term flux of pollutant directed to less contaminated compartment of this system

Physical chemical exchange processes in system "water-suspended sediments". A pollutant transfer between river water and suspended sediment is driven by the adsorption-desorption processes.

Physical chemical exchange processes in system "water-bottom sediments". The main chemical mechanism is radionuclide adsorption to and desorption from surface bed sediment is going simultaneously with the above presented diffusion to insitual water. For radionuclide transfer between bottom and water column most important exchanges occur within thin top layer of the river bed. The process is controlled by geochemical reactions of radionuclides with river water and sediment, and not always completely reversible. Chernobyl studies show the importance of the transformation of chemical species of radionuclides in sediments, i.e. transfer of the non-exchangeable forms into exchangeable.

Uptake and subsequent decay and excretion of radionuclides by aquatic biota. The process transfer radionuclides from water to bed sediment. Sometimes the water-bottom interface processes (diffusion, adsorption-desorpion, biota fluxes) could be combine under one determination - direct uptake processes.

Transfer processes between upper bottom layer and deep buried sediments. Through the thin top bed layer radionuclides could be accumulated into or depleted from the deeper bed sediment. These radionuclides are further mixed within the deeper river bed layers by diffusion, bioturbation and movements of bed sediment formation.

Due to specific properties of the diffusion and exchange processes in the various water bodies, one has to consider separately three areas: surface runoff, transport in rivers, and behaviour of radionuclides in lakes, reservoirs and coastal waters. The mathematical background of all these models is the advection – diffusion equation:

$$\frac{\partial C}{\partial t}+U\frac{\partial C}{\partial x}+V\frac{\partial C}{\partial y}+W\frac{\partial C}{\partial z}=\frac{\partial}{\partial x}\left(\mathrm{E}_t\frac{\partial C}{\partial x}\right)+$$

$$+\frac{\partial}{\partial y}\left(\mathrm{E}_t\frac{\partial C}{\partial y}\right)+\frac{\partial}{\partial z}\left(\nu_t\frac{\partial C}{\partial z}\right)-\lambda C-R_{w,s} \qquad \text{(L3.2)}$$

where ***C*** is the radionuclide concentration, ***U, V, W*** are components of flow velocity, ν_t is the vertical diffusivity E_t is the horizontal diffusivity, λ is the decay parameter, $R_{w,s}$ is a source-sink term, describing the interaction of the radionuclides in solute with the suspended sediments in a water column.

A similar advection – diffusion equation describes the transport of the radionuclides in particulate form.

$$\frac{\partial SC^S}{\partial t} + U\frac{\partial SC^S}{\partial x} + V\frac{\partial SC^S}{\partial y} + (W - W_g)\frac{\partial SC^S}{\partial z} =$$

$$= \frac{\partial}{\partial z}\left(\nu_t \frac{\partial SC^S}{\partial z}\right) + + \frac{\partial}{\partial x}\left(E_t \frac{\partial SC^S}{\partial x}\right) + \frac{\partial}{\partial y}\left(E_t \frac{\partial SC^S}{\partial y}\right) -$$

$$-\lambda SC^S + R_{w,s} \qquad \text{(L3.3)}$$

where W_g is the settling velocity of the sediment particles

The boundary conditions at the variable water surface $\eta(x,y,z,t)$ defines that the vertical flux of radionuclides through the surface is equal to the atmospheric deposition rate F

$$z = \eta(x,y,z,t): \qquad \nu_t \frac{\partial C}{\partial z} = F$$

The boundary condition at the level of the undisturbed bottom H **:**

$$z = -H: \qquad \nu_t \frac{\partial C}{\partial z} = -Z_* R_{w,b}$$

defines that the vertical flux of radionuclides in the water is equal to the flux to/from the top layer of the contaminated bottom sediment, with thickness Z_*. The horizontal advection-diffusion fluxes of radionuclides from sources or tributaries to the water bodies define the lateral flow boundaries. Specific for radionuclide transport models - in comparison with other water contamination models - are the physical - chemical exchange processes in the system “water - suspended sediments - bottom sediments ”, that define the structure of the terms $R_{w,s}$ and, $R_{w,b}$ in the equations (L3.2) - (L3.3).

The traditional approach in describing and predicting the fate of radionuclides on heterogeneous solids such as soil, suspended and bottom sediments is mainly empirical and is still based on the use of the parametrisation of simplified adsorption- sorption kinetics in particular of the equilibrium distribution coefficients $K_d = C^e_d / C^e$, - where C^e_d, is the amount of the contaminant adsorbed at equilibrium on the particles (suspended or bottom sediments) , and C^e is the amount of the contaminant left at equilibrium in solution. **The "water-solid" exchange term $R_{w,d}$** (d=s for suspended sediment and d=b for bottom deposition) is described by the linear adsorption equation

$$R_{w,d} = A_{w,d} M_d (K_d C - C^d) \quad \text{(L3.6)},$$

Assumption: concentration in pore water is equal to concentration above bottom

where $A_{w,d}$ is the exchange rate coefficient with the dimension $(time)^{-1}$. Often the adsorption rate is not equal to the desorption rate. M_d is the mass solid particles per unit volume (density or suspended sediments concentration). Equation (L3.6) is the basis for the definition of the exchange rates of radionuclides between the water phase and suspended matter ($C^d = C^s$, $M_d = S$, $R_{w,d} = R_{w,s}$) , and between the water phase and the top layer of the bottom sediments, Z_*, $M_d = \rho_s (1-\varepsilon)$, where ρ_s is the density of the sediment and ε is the porosity.

Mark Zheleznyak

But I will state the main ideas. When I say what is the basic approach, when I say about the flux of contamination between solute and sediment, for example I will take – we will make such experiments as full budget experiments. People from [Unclear], they took sample of soil from this floodplain, bring to Kiev Laboratory to some [Unclear] and put clean water above it and our task is to parameterize, to describe how quickly the water started to be contaminated. A very simple example I could use with the students, if I will take some amount of salty soil and put clean, fresh water above, and each day I will provide the measurement how salty is this water.

Day per day, water will be more and more salty. But in some moment, it stopped. It will start to be equilibrium. If I would like to have more salty water, I should add more salt to the water. But this process is described by this adsorption-desorption relation. The floods of contamination between two floods, between water and sediment is proportional. This constant is we have minus 10 [Unclear] rate of the exchange processes. Here, we have difference between real concentration of the sediment in the bottom. Kd multiplied by C [ph]is equilibrium concentration. Such is that when C started to be in equilibrium with Kd, this will get to zero. This flux will stop when you will have equilibrium situation.

The radionuclide concentration $\overline{C}^b$, averaged over the bottom layer, is the third variable (in addition to ***C*** and ***C^s^***) to be considered in the radionuclide transport in the surface water:

$$R_{w,b} = \rho_S (1-\varepsilon) A_{w,b} (K_b C - \overline{C}^b) \qquad \text{(L3.7).}$$

The boundary conditions for the equation of particulate radionuclide transport (2) defines a net zero flux of radionuclides through the free surface,

$$z = \eta \qquad (W - W_g) S C^S - \nu_t \frac{\partial S\, C^S}{\partial z} = 0 \qquad \text{(L3.8)}$$

and also equals the fluxes at the bottom due to the suspended sediment deposition rate q^s and the bottom erosion rate q^b :

$$z = -H: \; W_g S C^S + \nu_t \frac{\partial S\, C^S}{\partial z} = C^S q^S - \overline{C}^b q^b \qquad \text{(L3.9)}$$

- The dynamics of the contamination in the upper bottom layer is defined by the mass balance equation

$$\rho_S(1-\varepsilon)\frac{\partial(Z_*\overline{C}^b)}{\partial t} = -R_{w,b} + C_0^s q^s - \overline{C}^b q^b \qquad \text{(L3.10)}$$

As a basis for the simulation of the radionuclide transport on the basis of the equations (L3.2)-(L3.10) it is necessary to use the results from the hydrological/hydrodynamics modules (velocity U,V,W and diffusivity), and from the suspended sediment transport module.

The HDM consists of models of different functionality and complexity (box to 3-D). Model of lower dimensions are in general derived by the integration of the system equations (L3.2)-(L3.10) over spatial variables; either over the depth (2-D model COASTOX), over the river cross-section (1-D model RIVTOX) or over the water body compartments (the box models)

The distribution coefficient Kd is measured as usual within so called batch experiments – the sample of contaminated soil is covered by water and than the dynamics of concentration in water and sediments is measured.

The total activity water+sediment is a constant

I[tot]= I [water]+I [pore water] +I [bottom sediment] = I_0

$$I = \left[(h+\varepsilon Z^*)\bar{C} + \rho_s(1-\varepsilon)Z^*\bar{C}_b\right]A$$

where $\bar{C}$ depth averaged water concentration, $\bar{C}_b$ - concentration in sediment, averaged over upper bottom contaminated layer, Z^* - depth of this layer, h – water depth, ρ_s - density of bottom sediments, ε porosity, A -bottom area.

Therefore, if I have such situation that – I'll give you example, I have this sample, it's mass of contamination inside this glass of water and sediment. I have here the level of water, large amount of pure water multiplied on concentration in water. Here, it's amount is pure coefficient and density of the sediment and concentration in sediment. This is area of this glass. This value should be constant, because if I take contaminated sediments in pure water, initial moment, all contamination is in sediment.

After sometime it will be redistribution of this contamination between these two parts.
But in any case, it's equivalent system. It will be continued, so the sum will be constant

Integration of the above equation over the depth will provide
(Zheleznyak et al, 1989)

$$\frac{d(h_* \bar{C})}{dt} = -\rho_s (1-\varepsilon) Z^* a_{13} (K_d \bar{C} - \bar{C}^b),$$

$$\frac{d\bar{C}^b}{dt} = a_{13} (K_d \bar{C} - \bar{C}^b),$$

As usual $h \gg \varepsilon Z^*$ therefore we could use further $h_* = h$.

If $\bar{C}$ (0)=0 and $\bar{C}^b(0) = \bar{C}_0^b$, then

$\bar{C} h_* = (\bar{C}_0^b - \bar{C}^b)\ \rho_s (1-\varepsilon) Z_*$.

and applying this equation and I'll describe how will we change contamination in water. I have this coefficient of change between water and sediment in both sides, described with fluxes.

Introducing parameter $\beta = \dfrac{\rho_s(1-\varepsilon)Z_*}{h_*}$ the above system could

be reduced to one equation

$$\frac{d\bar{C}}{dt} = -a_{13}(K_d R + 1)\bar{C} + a_{13}\beta\bar{C}_0^b \quad .$$

For the initial condition $\bar{C}(0) = 0$ it solution is:

$$\bar{C} = \bar{C}_0^b \frac{\beta}{\beta K_d + 1}\left[1 - \exp(-a_{13}(\beta K_d + 1)t)\right] .$$

or

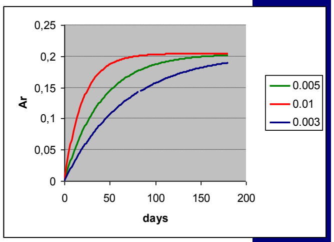
$$\bar{C}^b = \frac{\bar{C}_0^b}{\beta K_d + 1}\left[\beta K_d + \exp(-a_{13}(\beta K_d + 1)t)\right]$$

In experimental studies it is used ratio of water activity to total activity

$$A_r = \frac{\overline{C}h}{\overline{C}h_* + \rho(1-\varepsilon)Z_*\overline{C}^b} = \frac{\overline{C}}{\beta \overline{C}_0^b}.$$

Then the solution is

$$A_r = \frac{1}{\beta K_d + 1}\left[1 - \exp(-a_{13}(\beta K_d + 1)t)\right]$$

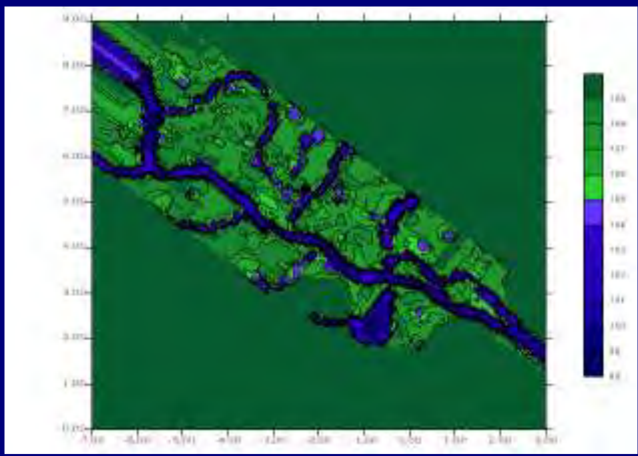


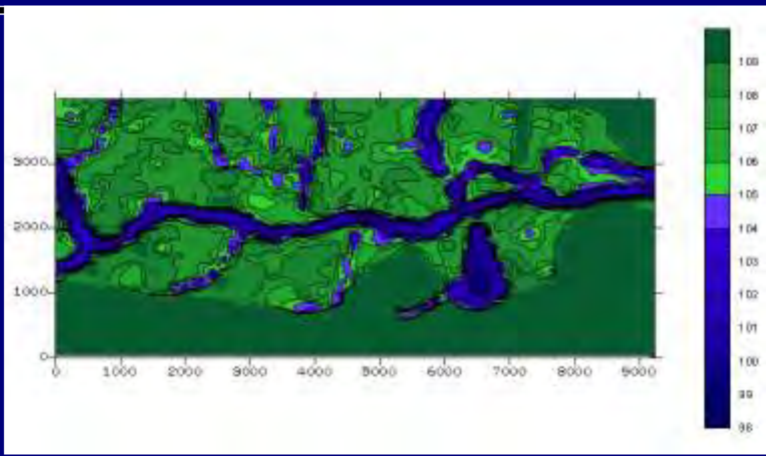
This formula was used for the processing of the experimental data from Pripyat River floodplain (Voitsekhiovich et al, 1989). For ^{90}Sr it bring following values K_d = 0.05 m^3/kg, a_{13} = 0.005 day^{-1} when Z_* = 5 см.

When they make solution of this system of equation, I could find it is in analytical form and annually [Unclear] exponential [Unclear] that depends on two parameters, on Kd and this exchange rate coefficient.

What we did for this floodplain? As I told my colleagues came in '86-'87 to the floodplain, took the samples of soil, put this water above the soil, day per day they provided measurements how change – you see that equilibrium could be even sometimes after 100 days, 150 days. It means that if territory is flooded, we have flooding. We don't continue 100 days. It could be only several days. It will be here in this area of [Unclear]. What was important? We received this experimental task and we calculated these parameters, Kd and the exchange rate from this experience.

Modeling of the radionuclide wash out from the heavy contaminated Pripyat floodplain for different water protection scenarios





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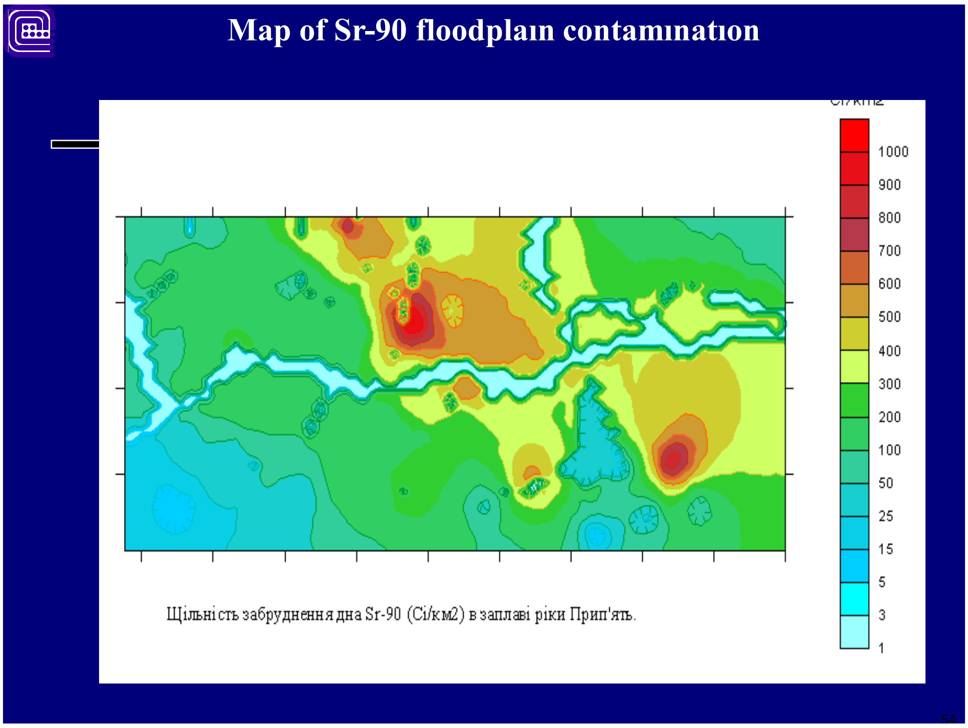
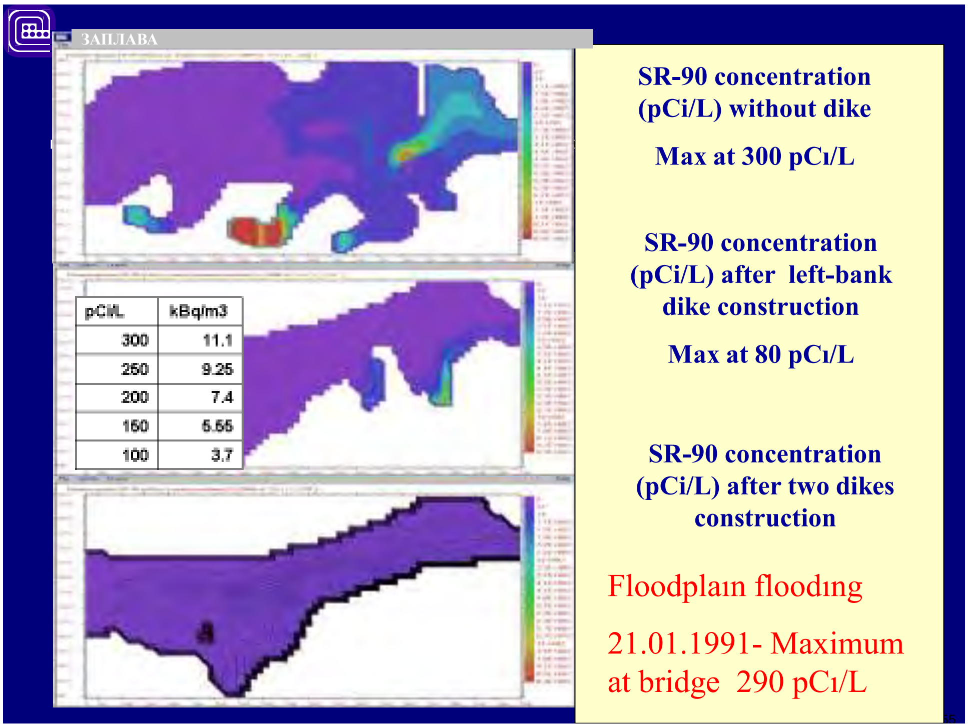


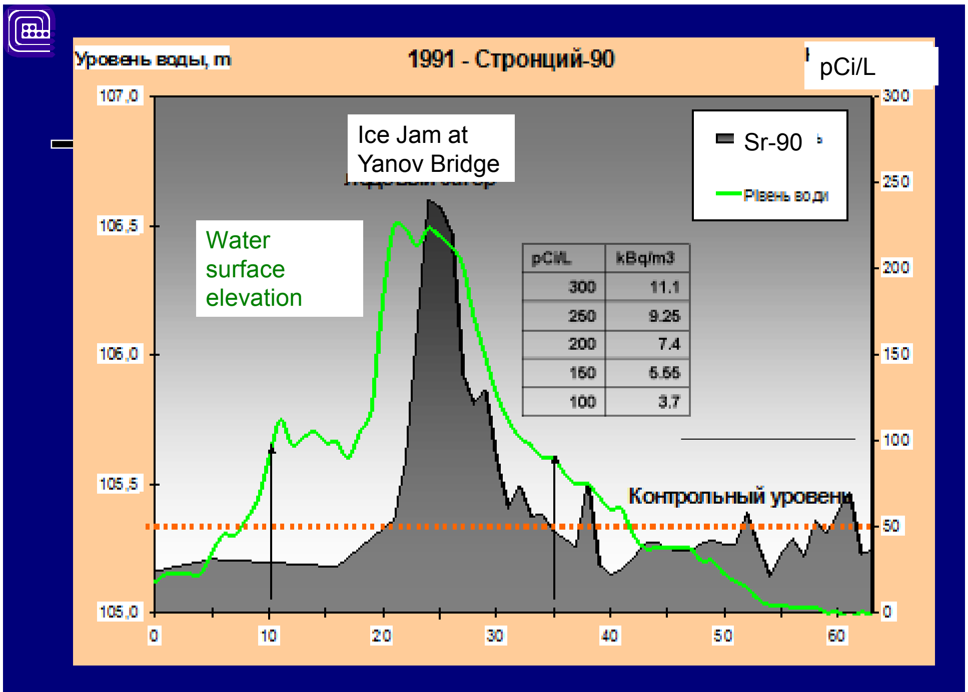
Therefore, after that we used the model equation, such parameterization of exchange with the parameter that's used in the floodplain. You see this floodplain territory. We apply two-dimensional model that was equivalent by a degree. We see the contamination in the bottom. We have equation of the transport of contaminants above this territory plus these fluxes from bottom in this equation plus parameter that we take from this soil as a result. We receive such results.



If territory will be flooded, the contamination will be at [Unclear]. But it was fine because in 1986, Soviet Union, it was not a country of mercury. It was a country of [Unclear] and so we're working on [Unclear] with no time to [Unclear]. But here is a table to simplify understanding. As we have the [Unclear] it's all the results for – I didn't reconstruct the pictures. It's 11 to a degree and it's a good parameter if there is a high concentration of strontium now, it's [Unclear]. In this moment, we have maximum permissible level we have.

We demonstrate that if floodplain will be flooded, concentration increased significantly. It will be three times more than maximum permissible level. As a result of the modeling, it's very clear, understandable, if they are stable from the salt and I put some amount of water above the stable from one side to another side. In which case, water here will be more salty. Relatively, however, a very small amount of water and very high amount of water, it's clear that the worst case is very small amount of water, because in small amount of water propagated above this salt table. I will receive high concentration of salt in the water.

Here in the floodplain, we found that most dangerous situation can be if all this territory will be flooded by the small amount of water. After that we played with countermeasure, different kinds of countermeasures and we played with the dikes' construction, one dike on one side and demonstrated in this case it will be fall down concentration here to 80 pCi/L. Two dikes fall down to 50 pCi/L; it was here. We prepared this justification of this construction. It was decision of our government to start to construct these dikes. I will say a little also about justification. But before it was constructed, we have big experiment. Territory has been flooded.

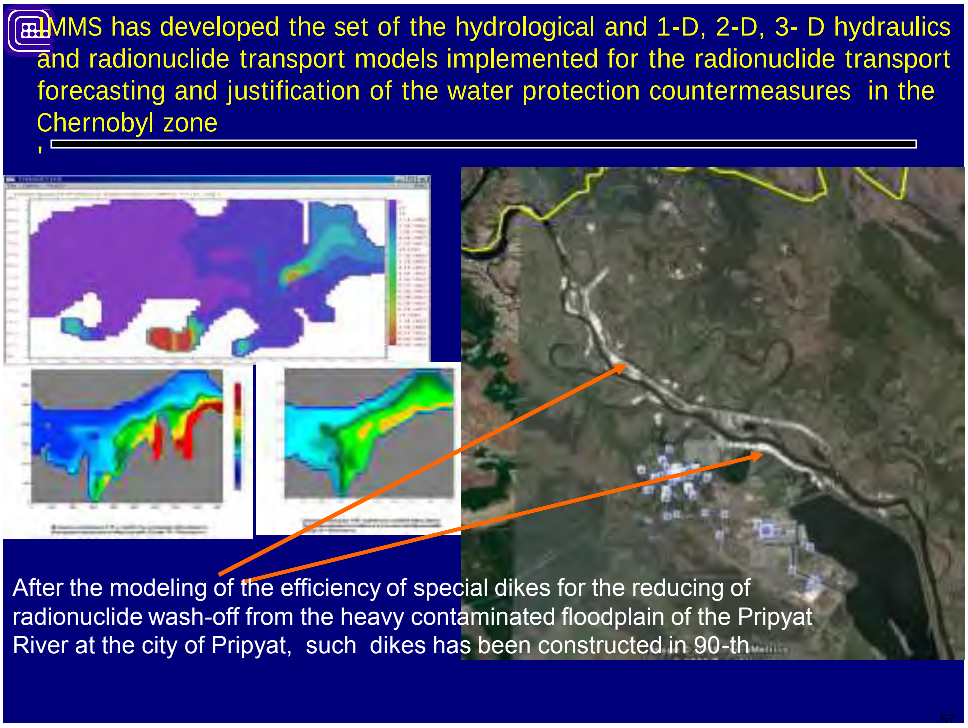


Sr-90 Concentration and water elevation in Pripyat River in January 1991 at Chernobyl

What was the result? The result was that we have concentration that started with the ice jam, increasing of water level.

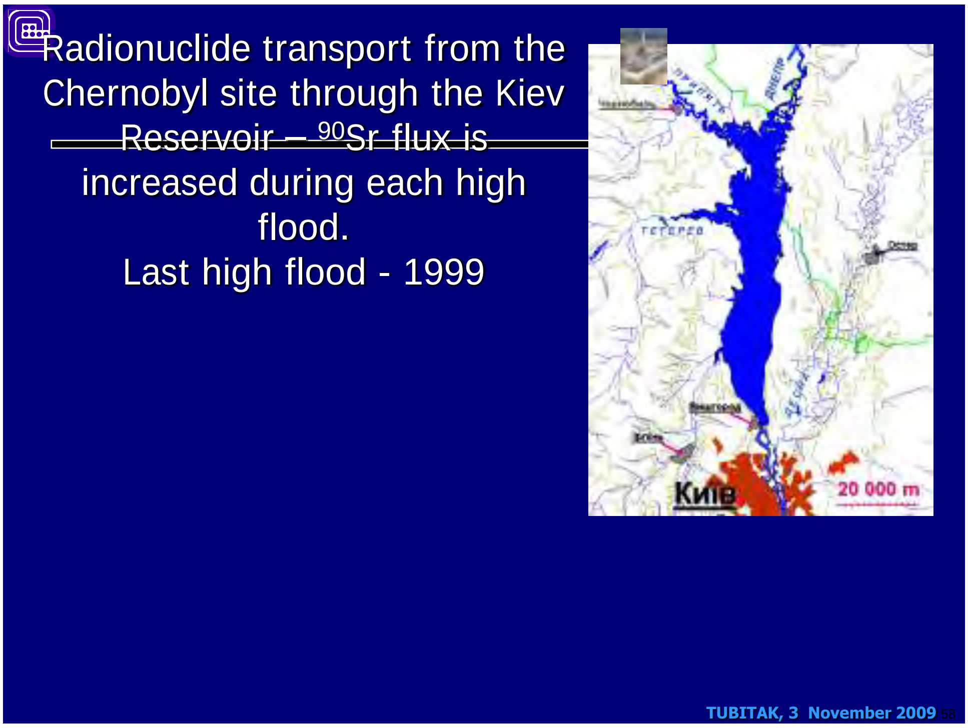
We have concentration up to near 250. In Chernobyl in downstream these plains, but near this bridge, it was near 300. It's maybe most large scale experiment of the model confirmation [Unclear] participate. I have double feeling because from one side, I was happy that we were successful in the prediction. From other side as people who lived in Kiev, I wasn't happy. The strontium comes to my city, because it started increasing strontium.

What was the brilliance of the studies such as why we predict strontium, because we use monitoring data, we found site-specific parameters, as I told you. We used reasonable parameterization that described physical processes. Therefore, we could predict the situation.



First about this, as I told you as a result, both dikes were constructed, first this one and after that this one and now we have this.

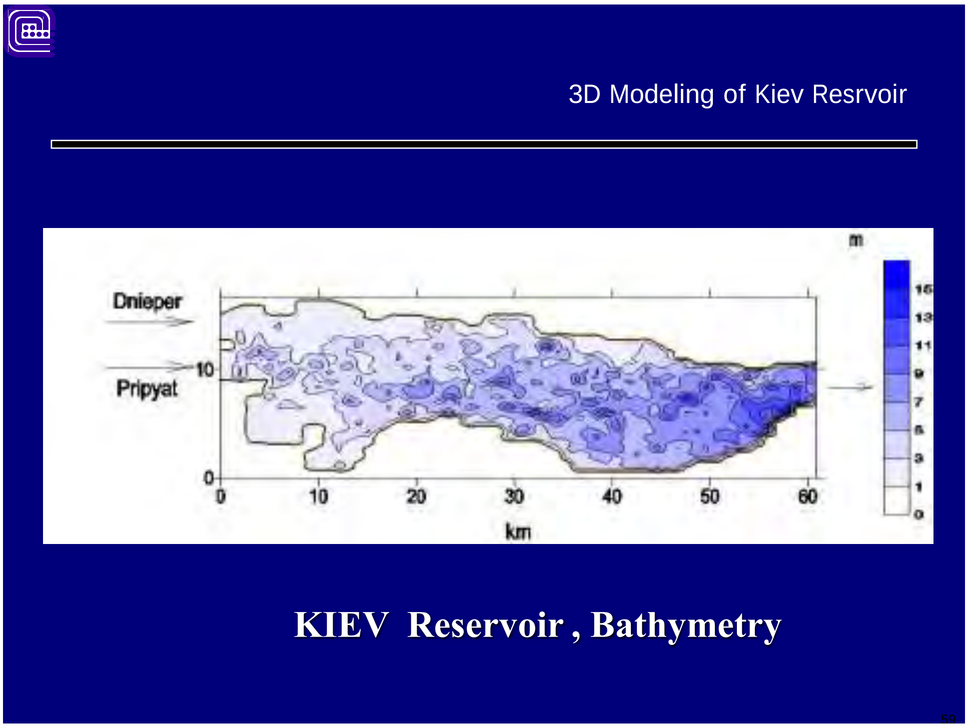
It happens in winter, not due to the flood, but due to the ice jam, because here is a bridge and it was very cold winter, 1991, and here near the bridge was ice jam. Water could not come through. Water came to the floodplain. It was our worst scenario, because all floodplains were flooded, but with small amount of water.



Above situation in Kiev at this moment, so 300 picoCuries come from the Pripyat River to Kiev Reservoir, but it was diluted here, big amount of more clear water in the reservoir, 300 kilometers.

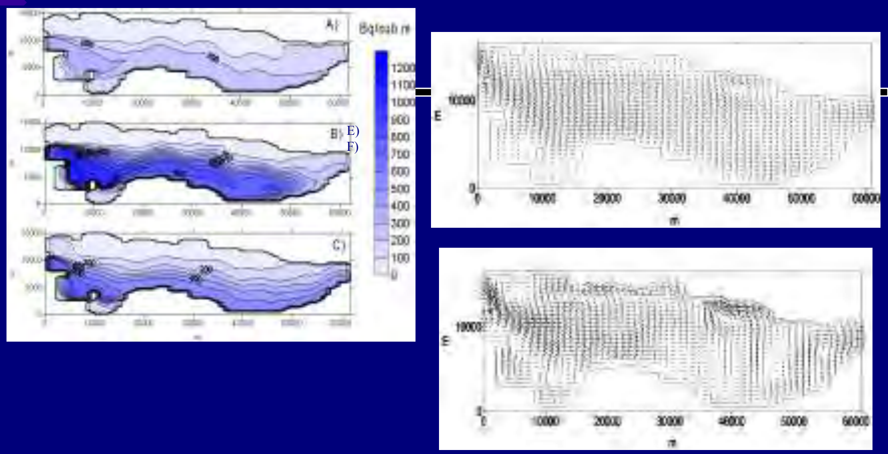
It was a very slow process of propagation, not high speed; it's interrupted and takes near 1 month.

As our calculation result demonstrated in Kiev, we'll be increasing from 7 picoCuries per liter to 40 picoCuries per liter, which means that six times increasing, but below maximum permissible level. But in any case, city has time for preparation. City received water for drinking from two sources, from Dnieper River and from the Desna River. Before this contaminated water comes to Kiev, Kiev water intake was switched to from Dnieper and all water taken from the Desna River.

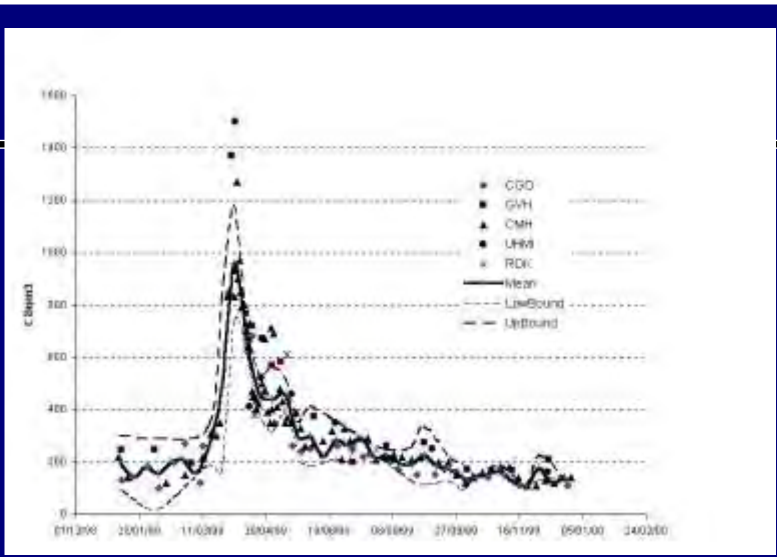


For this simulation, we used atmosphere to two-dimensional model. We use three-dimensional model in Kiev Reservoir.

After that we provide by one-dimensional model forecasting downstream to Kakhovka Reservoir, for Zaporizhia [ph] Reservoir, and also not a better result of the comparison of the model and received results.

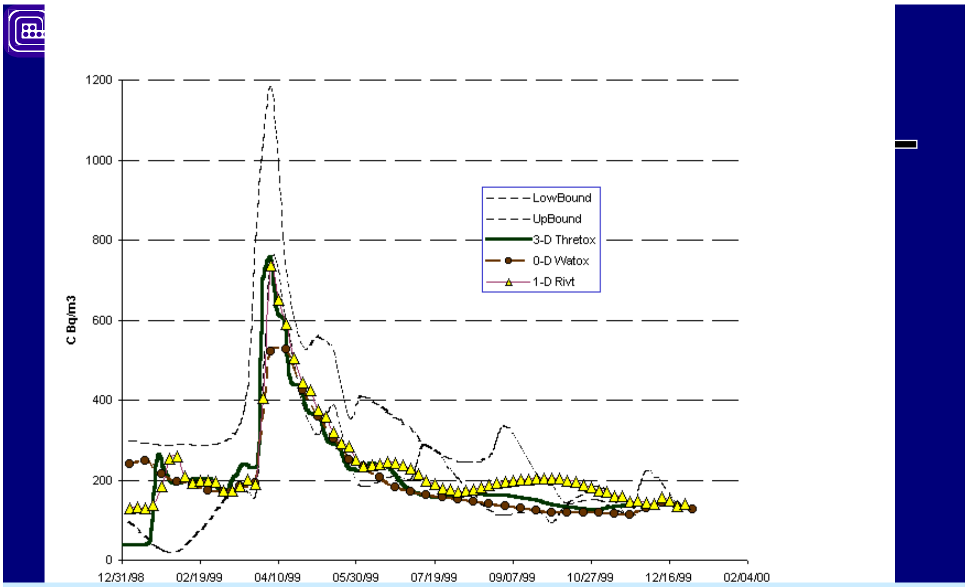


Simulated by 3-D model concentration of ^{90}Sr a the surface of Kiev Reservoir in A) 5 March, B) 25 March and C) 15 April 1999 and simulated currents at the bottom E) and at the surface for the conditions of N-W wind, wind velocity |W|=5.3 м/s, maximum currents velocity |U|max=16 cm/s, Q=1100 m^3/s.



Concentration of ^{90}Sr in Kiev Reservoir at dam of Hydro Power Plant in 1999 measured by different institutions and results of the statistical processing of these data – mean value, upper and lower bounds of the confidential band.

We calculate the currents in the reservoir. In 1993, dike was constructed and next large flood was in 1999. It also was increasingly in Kiev, now in [Unclear] up to 700 [Unclear]. But if this dike wasn't constructed, this peak will be much, much higher, so we prevent a city from such increasing and we compare different models.



Concentration of ^{90}Sr in Kiev Reservoir at dam of Hydro Power Plant in 1999 simulated by 0-dimensional (box) model, one-dimensional model and three-dimensional model in comparison with the bounds of the confidential band of the measured data

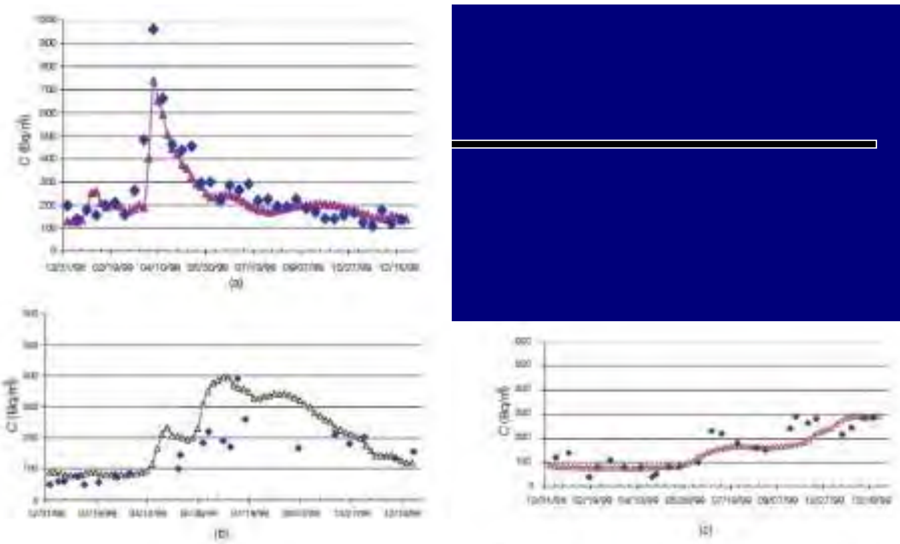
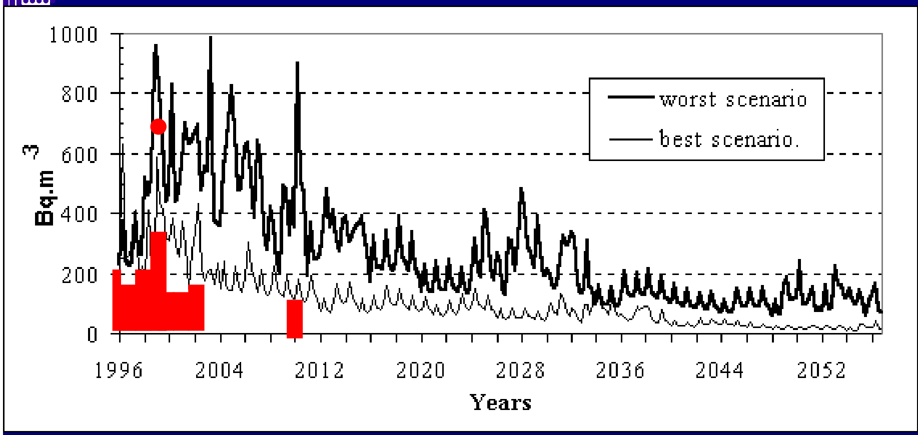


FIG. 9.4. Ten day averaged concentrations of ^{90}Sr at the dams of the hydropower plants of (a) Kiev reservoir, (b) Zaporozhe reservoir, (c) Kakhovka reservoir in comparison with simulation results (triangles) of the 1-D model. C, ^{90}Sr activity concentration in water.



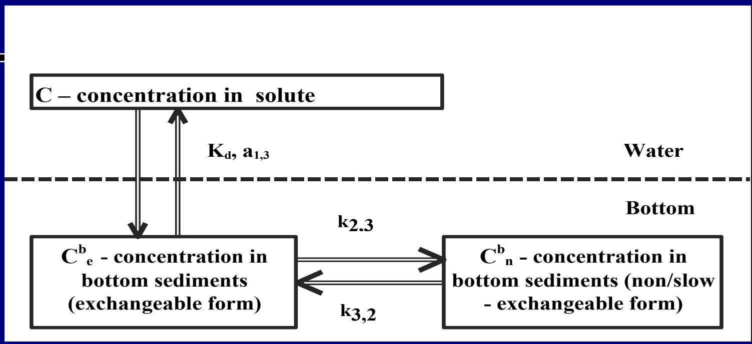
Simulation of long-term fate of ^{90}Sr in Kiev Reservoir

Input scenarios of low- and high- water hydrological years in assumptions of absence of emergency situations in Chernobyl zone .Simulation has been done in 1995. The measured data 1996-2012 are close to the avaraging of the "best" scenario

Also, we played with the long-term scenario. Why it was strange request but we took strange? It was request to make prediction of contamination of the Dnieper River for 70 years after the accident. It means to 2056. Why for 70 years, because it was necessary to calculate the doses, the doses that people received after the accident. Of course, how to make prediction for 70 years? It could be only used scenario approach. We know now that amount of strontium that was washing out to the reservoir depends on the amount of water, big floods.

Therefore, we make two scenarios, one scenario is the small floods, another scenario is the big floods. We took historical floods, historical data about the flow and speed of the river and construct future scenario. We say that the two potential scenarios. Observation for the scenario was calculation of the dose. Here, the red is the result of real monitoring. You see that reality that is [Unclear] ratio is a little bit higher, but it's still very close to our best scenario, but this red point is not annual [Unclear] but it's a real [Unclear] versus the peak of 1999.

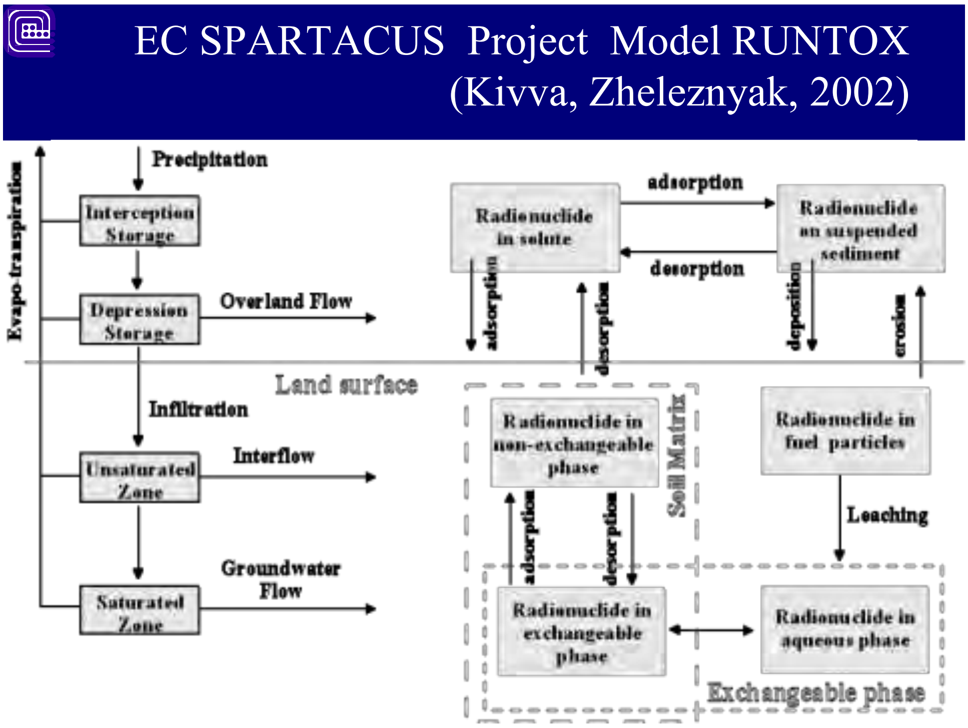
Two-step kinetics - more detailed description of Cs137 adsorption- desorption processes



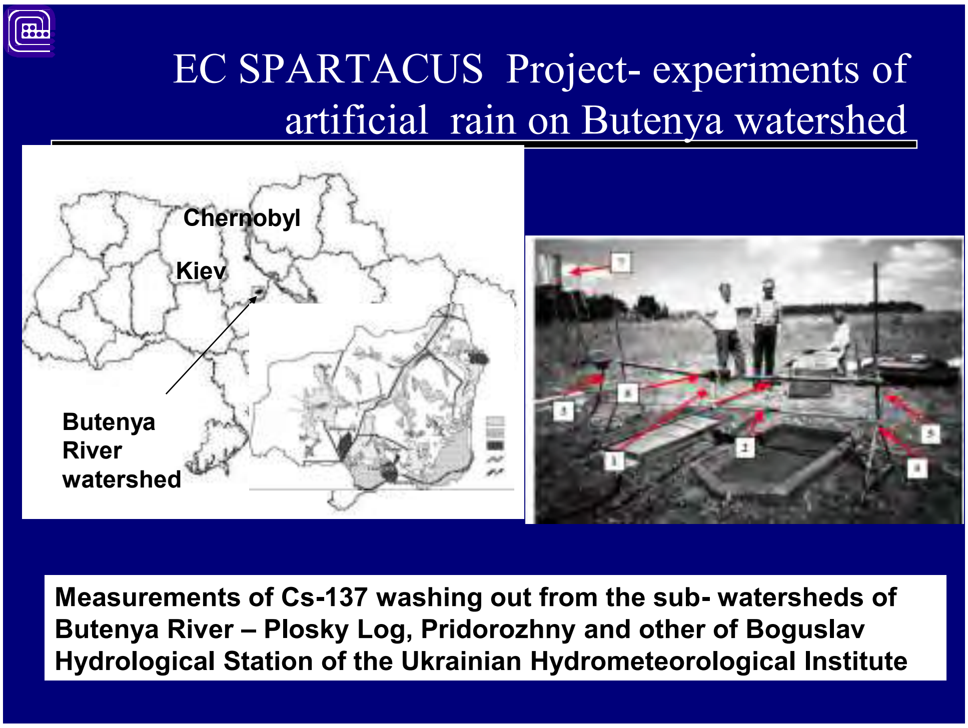
$$\begin{cases} \dfrac{\partial C}{\partial t} = -a_{1,3}(KdC - C_e^b)\rho_s z^*(1-\varepsilon)/h \\ \dfrac{\partial C_e^b}{\partial t} = a_{1,3}(KdC - C_e^b) - k_{23}C_e^b + k_{32}C_n^b \\ \dfrac{\partial C_n^b}{\partial t} = k_{23}C_e^b - k_{32}C_n^b \end{cases}$$

I told you about the exchange of the radionuclides. Now we make our model more complicated, but it's usual complication, because now we have the solution that soil has two kinds of the cesium, cesium in exchangeable form and soluble form, water exchangeable form and cesium in slow exchangeable form.

As I said from one-step kinetic skill [ph] to two-step kinetic skill, so now equation of the exchange in the bottom a little bit more complicated, but it better described the process of the exchange.

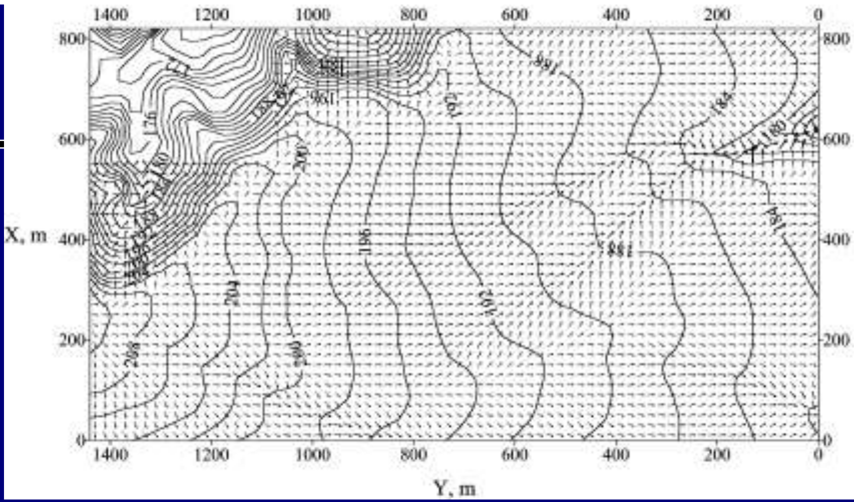


not only overland flow, but also takes into account flow in separated zone and groundwater flow in separated zone and exchange between this and also exchange of radionuclides in the soil.



Yesterday I was in your experimental site near Fukushima, where you try to collect data about erosion of radionuclides from the watershed, but of course you're not the first, because the similar study was provided in our case, because we should calculate the radiation since the washing out from this small watershed.

This institute where [Unclear], they have experimental station, not near Chernobyl, but south from Kiev, near Butenya River, and they provided their experiments, not such sophisticated equipment that you have now, in 1996, but provided also small tools and larger tools provided the experiments of the calculation of contamination.

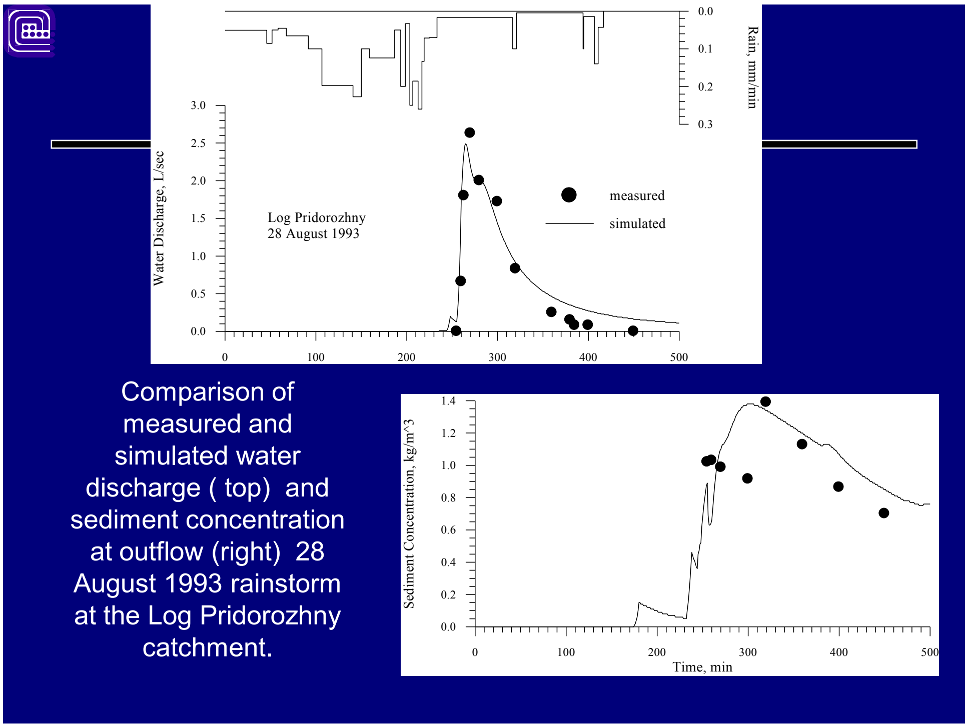


Overland flow simulated for Log Pridorozhny watershed during peak of the rainstorm 28 August 1993 with the lines of DEM

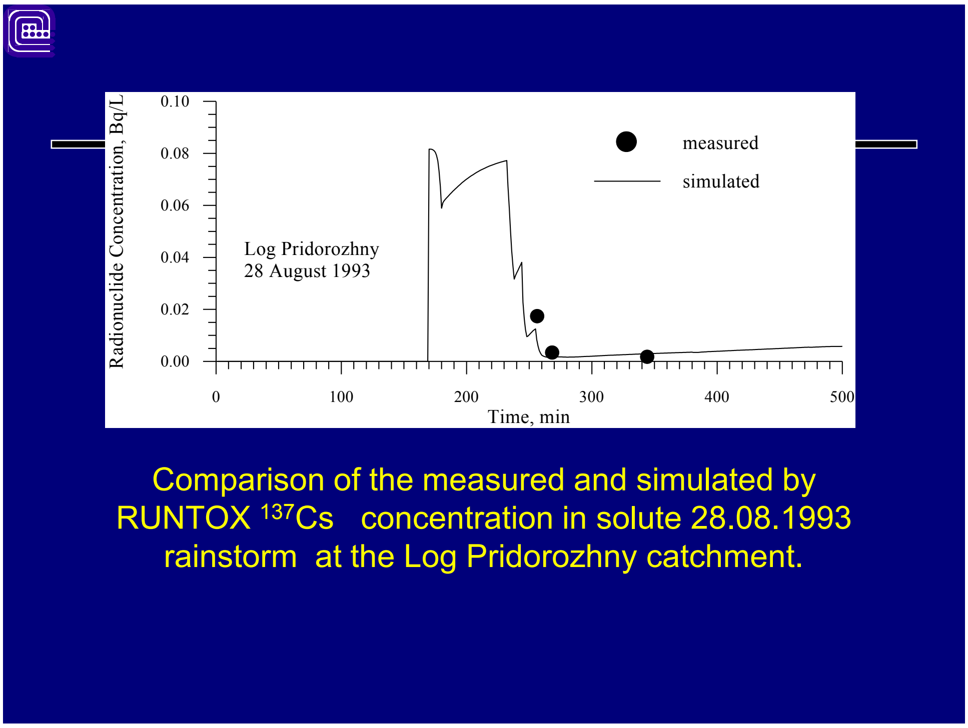
Log Pridorozhny is agricultural catchment located in upper right-bank of the Butenya river basin. Area of the catchment 0.40 km2
. Length 1.21 km. Average width is 0.33 km. Average slope 22.7%,

We developed the model that takes into account all these processes, two-dimensional model that covered all these small watersheds, experimental watershed, its length, 1.21 kilometers and area 0.40 square kilometers.

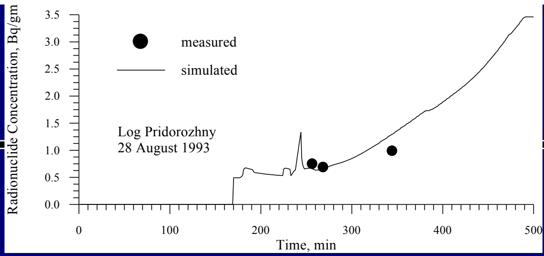
We calculate from this watershed by this model you see overland flow, but this model is also taking into account,



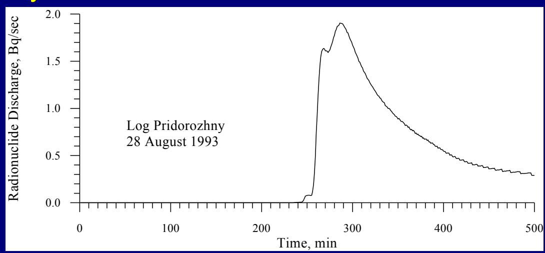
Test this model for floods, rainstorm floods. It’s also sediment concentration in the outflow and cesium.



But for cesium, we have no good enough set of the data because they started too late to take the samples from this, as you know. But in this, we have another such kind of experiments, but mainly for water and sediment levels and also some another experiment was provided directly in the Chernobyl zone.

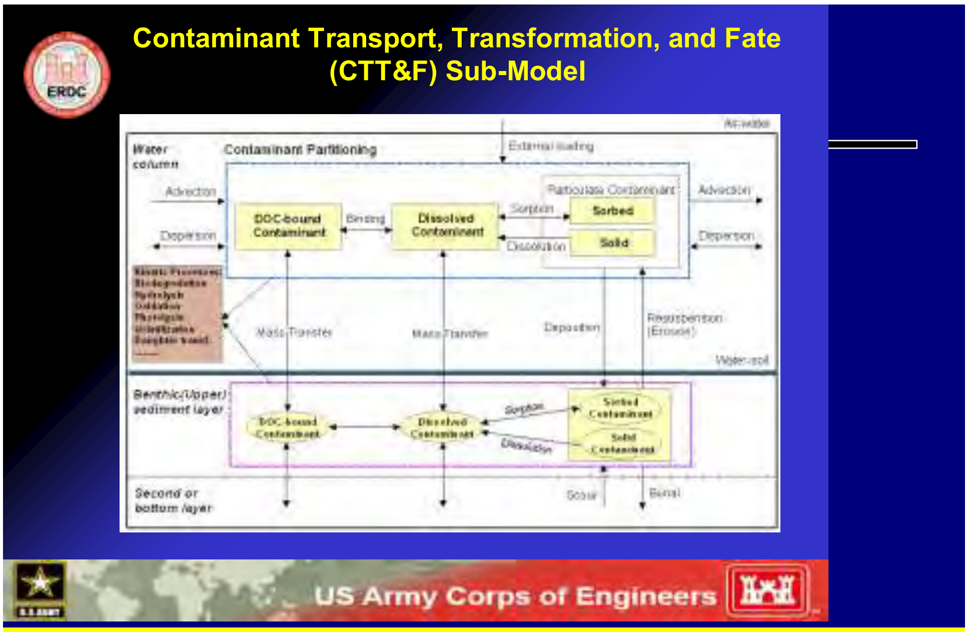


Comparison of measured and simulated radionuclide concentrations on suspended sediments for the 28 August 1993 event at the Log Pridorozhny catchment.



Discharge of 137Cs on suspended sediments for the 28 August 1993 event at the Log Pridorozhny catchment.

We see now concentration of cesium. Here is concentration of cesium in solute. Here is concentration of cesium in suspended sediments, but this is increasing. It's because it [Unclear] fast of the overland flow. Overland flow is covered by a very thin film of the model. Therefore, we have increasing concentration, but it has influence on the general flux of radioactivity, because general flux of radioactivity is high concentration but in a very small amount, but general flux was in this way. It was our study in the project that finished around 2002.

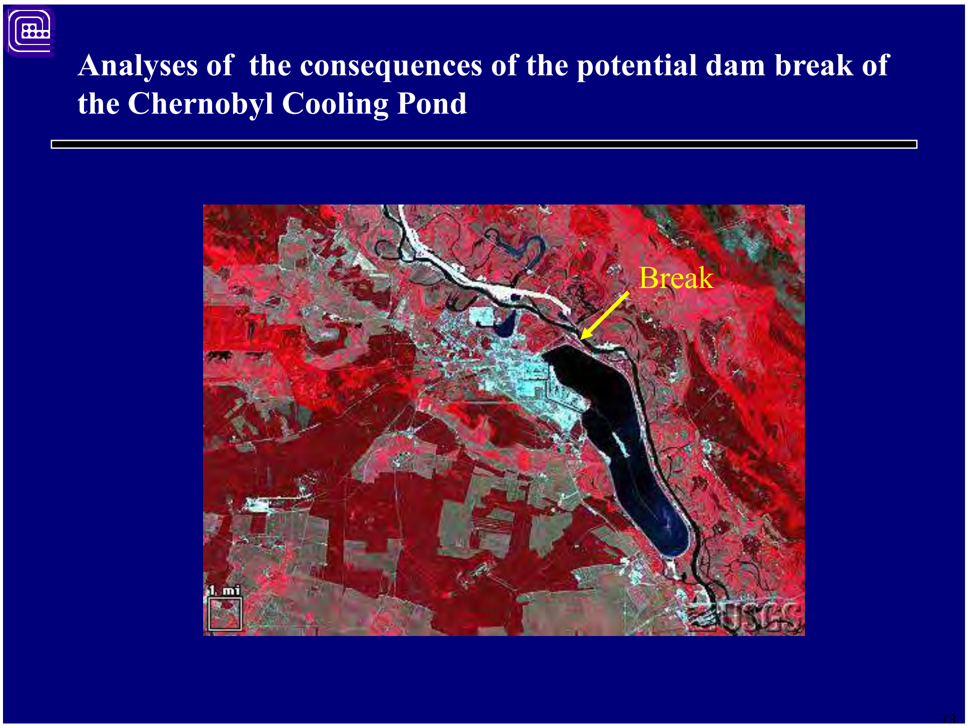


CCT&F – contemporary model of contaminants (radionuclide) simulation on watersheds of USACE that refers to our SPARTACUS RUNTOX model as basis of the approach

But after that Americans in US Army Corps of Engineers, they developed a similar model.

Its name is CCT&F that includes a lot of the schemes similar to that I presented to you. They have direct reference to our model. They use in their model they use our approaches that we applied in our model and refer to our modeling. Now we prepare a proposal for Chernobyl Zone Study for testing of this American model in Chernobyl area, experimental site.

Our idea is to apply both our models and American models to your site. My proposal that I thank you in our city proposal includes application of CCT&F, in principle the same basic principle that we applied and our model that we used that I demonstrated to you early, to work in Chernobyl zone watersheds, new program experimental and to work with your watersheds. Yesterday last site, absolutely good for such kind of study, because we could apply that.



I will say a few words. We have no time. I have to continue like for maybe next 15, 20 minutes, not 50, but 15, a few words about situation now in Chernobyl. What problem we have now? Cesium, we have a problem with cesium in general. Cesium, it's fixated after 25 years, fixated. You shouldn't forget that cesium and strontium, they both have decay time for excess years.

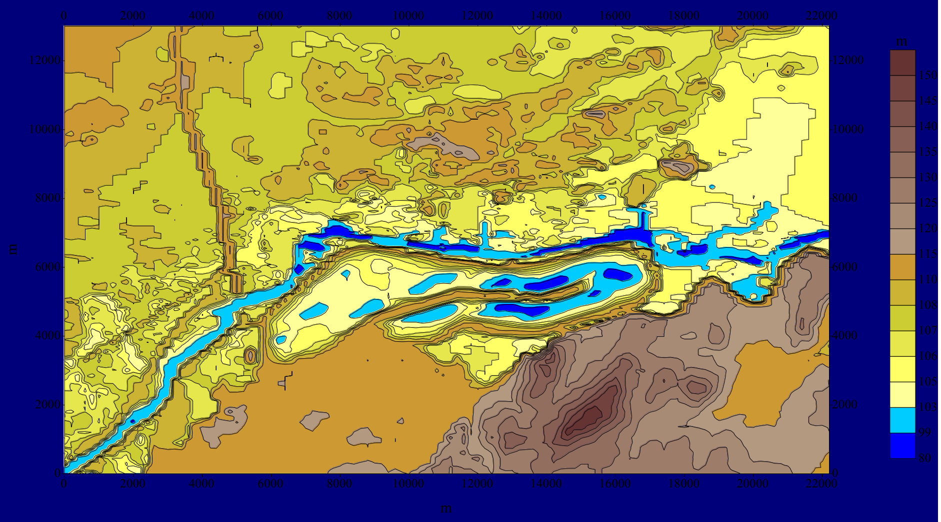
Now it happened, cesium and strontium decay, but what you improve. You see that big water volume, very highly contaminated Chernobyl cooling pond. The water level here is 6 meters higher than in the river. As nuclear power plant worked, pumping system worked to pumping the water to this reservoir, because all this dike is from [Unclear], it's filtration of water run through the dike. If you stop this pumping, water level immediately – not immediately – but will fall down to 600 low.

What happened in this case? Now, we have here extremely contaminated bottom sediments, the highest level in all this territory around. But if it will be on the surface, it could be dry. People are afraid that the story that happened in [Unclear] because it was such a story that was [Unclear] that it through the time was used to put the [Unclear] of the lake radiated with liquid [Unclear]. After that people forget about this lake, stopping the activities there. These lakes started to dry. All this former sediments of mud started to build on the surface. One day a tornado came. This tornado came through this lake, former lake, took this dust, former mud from the bottom and pushed this dust to the city nearby areas.

People received really high doses. Therefore, the similar precaution that if water falls down, it's little bit dry. If tornado is not very frequently, but in our area, we still have tornado. If tornado takes this from the bottom, it could be a high level of radioactivity and, therefore, now a different kind of option is considered. One of the options, diminish step by step water level and provide some activity to put different kinds of the vegetation, bushes, very little grass to fix this soil to prevent from the wind blowing. But before it started, today this water level is 6-meter high and we should calculate these.

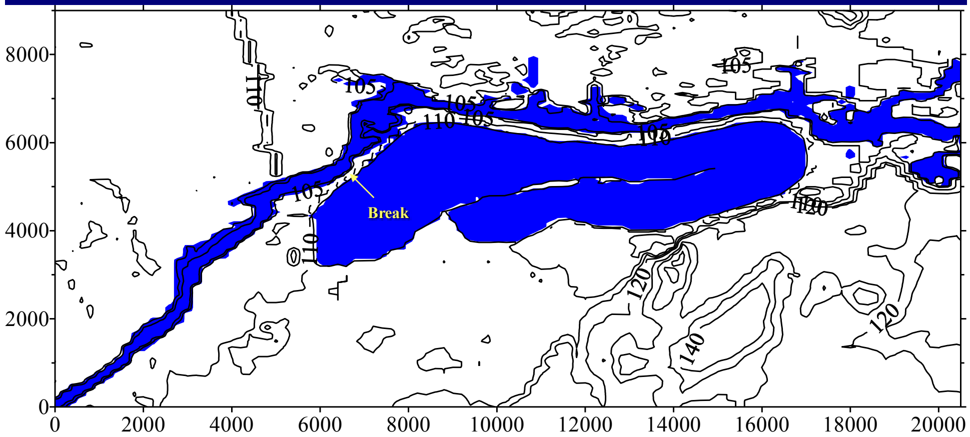
What happened if this dike will be destroyed, because it's clear that water will be propagated downstream and the water is very contaminated and we should know the level of these?
Therefore, we provided the special task, we destroyed the dike here and we calculate topography of the area.

Water level in the Cooling Pond is 6 m higher than in the Pripyat River

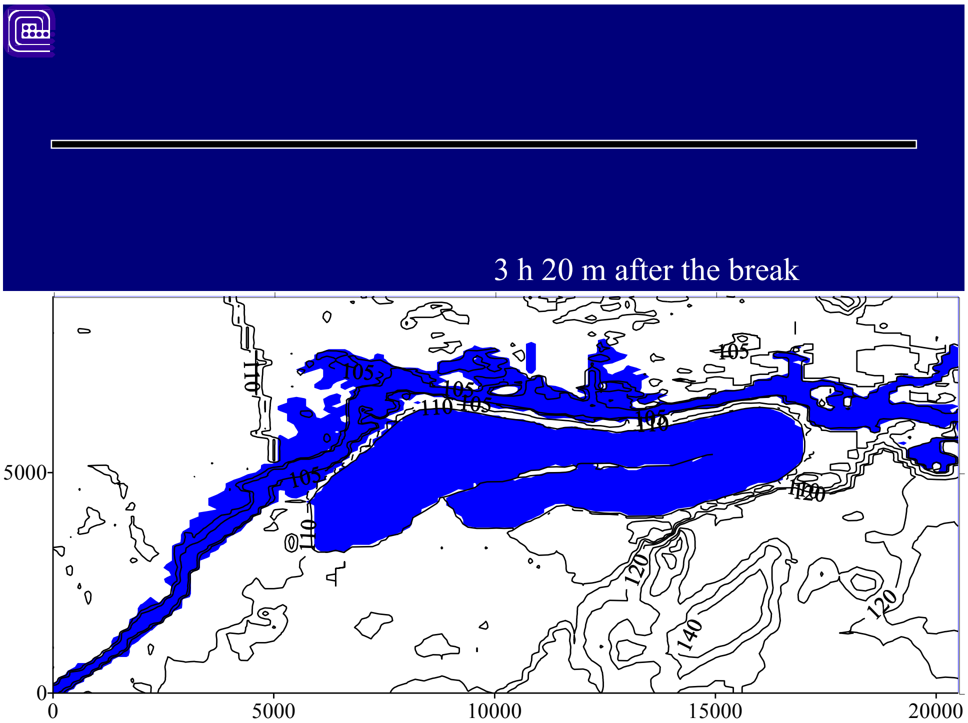


Simulation of the inundation zones in a case of a break of the dam of the Chernobyl Cooling Pond

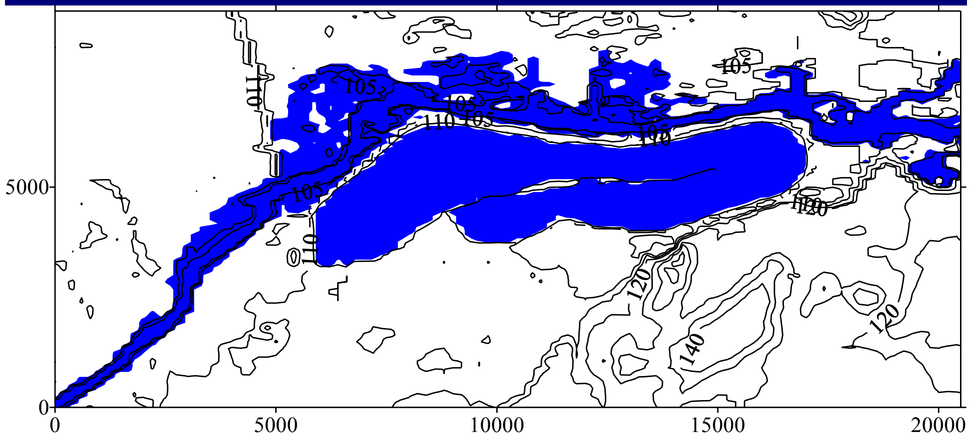
Before the break

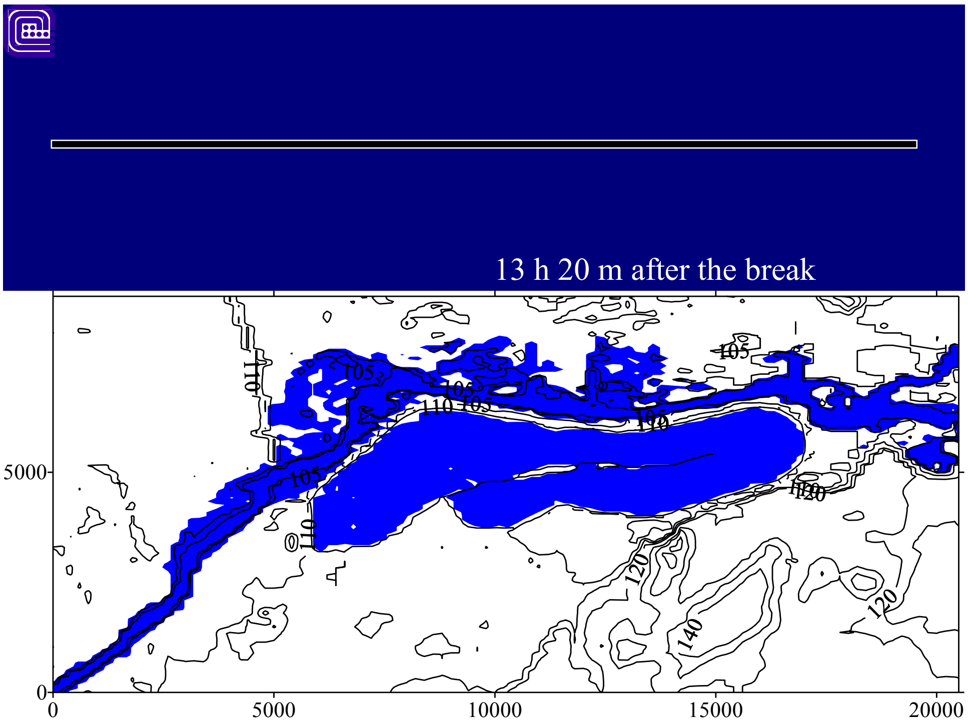


We apply two-dimensional model, organize a break, and step by step calculate how water is propagated,

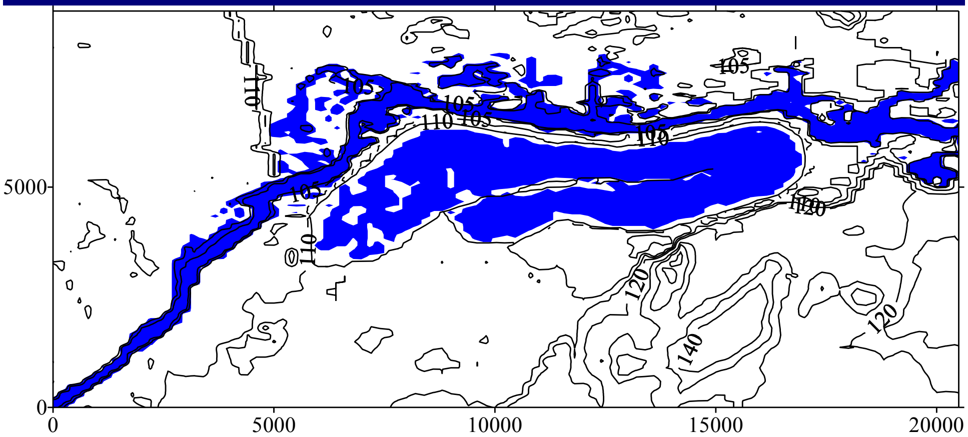

3 h 20 m after the break
105
110
120
140
0
5000
10000
15000
20000

8 h 20 m after the break

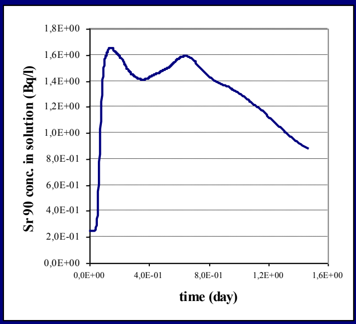


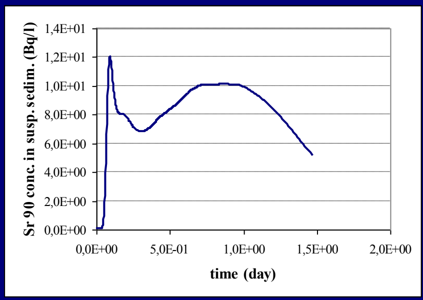

13 h 20 m after the break
105
110
120
140
5000
0
10000
15000
20000

30 h after the break



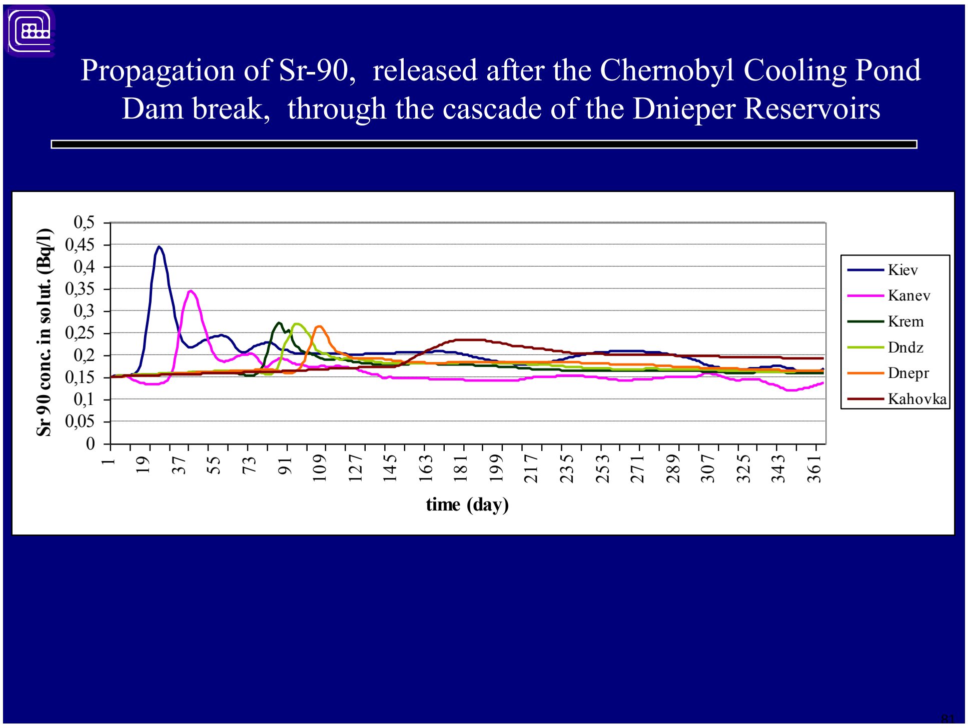
Temporal distribution of crossectionally averaged concentration of Sr-90 downstream the Cooling Pond after dam break and release via 150 m breach





Sr-90 Solute

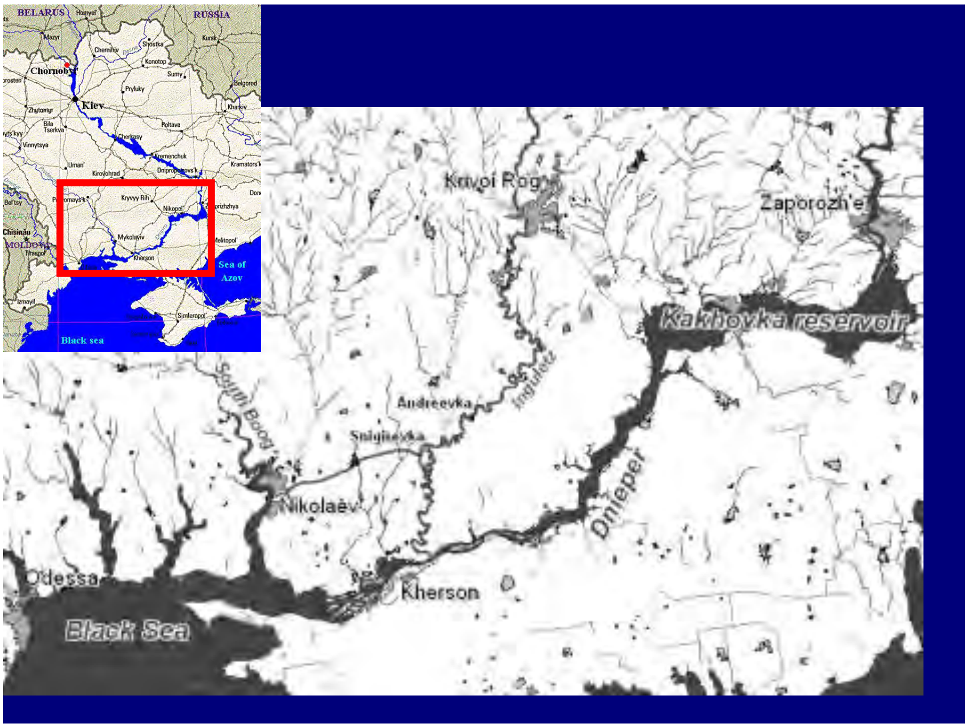
Sr-90 Suspended sediment



at the same time released from the cooling pond. After that, we calculate consideration in soluble sediment of cesium and propagate all these Dnieper reservoirs. How to propagate?

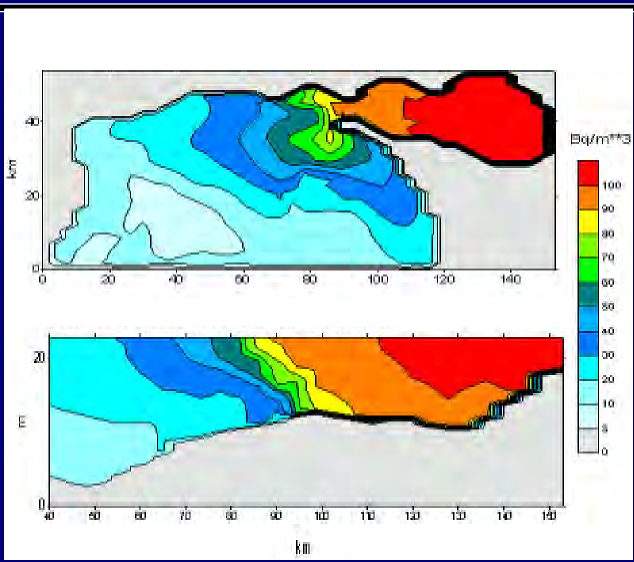
We demonstrated that risk is not very high, that risk of the increasing contamination, of course it's increasing three times near Kiev, but it will be less than last food in 1999. It was calculated maybe 10 years ago with the [Unclear] up to now, they continued to discuss what to do with this cooling pond, but maybe in nearest time,

Assessment of a fate of the Chernobyl radionuclides in the Black sea

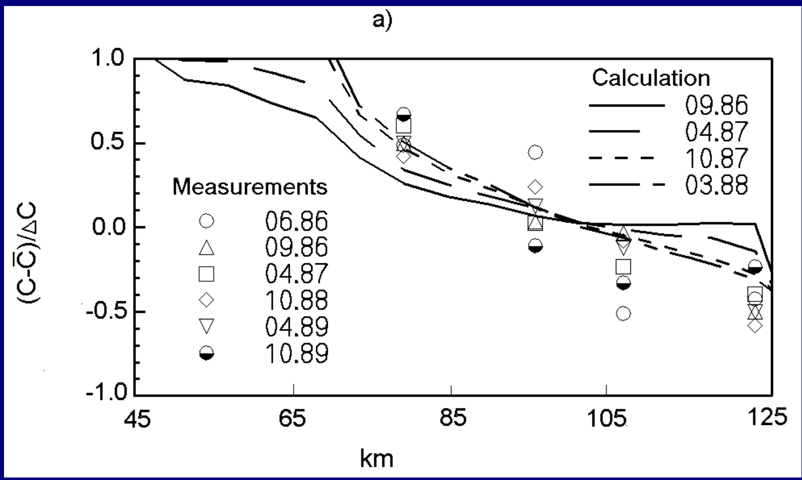


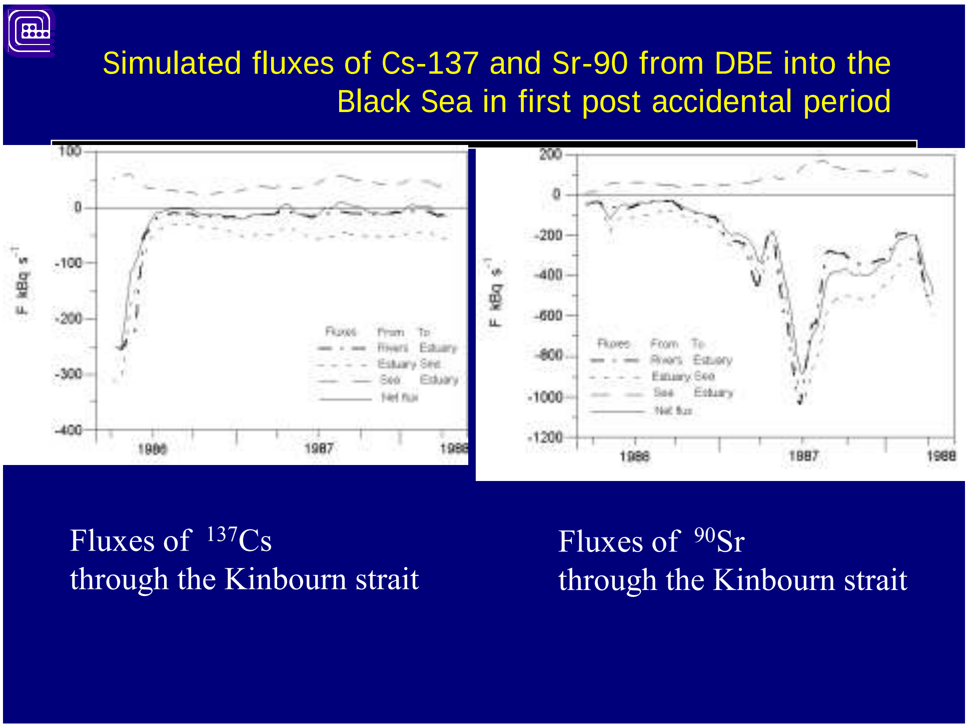
it will be shut down and water will diminish. Also I'll tell you we calculate fluxes to the Black Sea and, of course, so we have some experience with the coastal water simulation.

Simulation of Sr-90 release from the Dnieper-Boog Estuary to the Black sea



Measured and simulated concentrations of Cs-137 along the DBE and adjacent Black sea coastal area

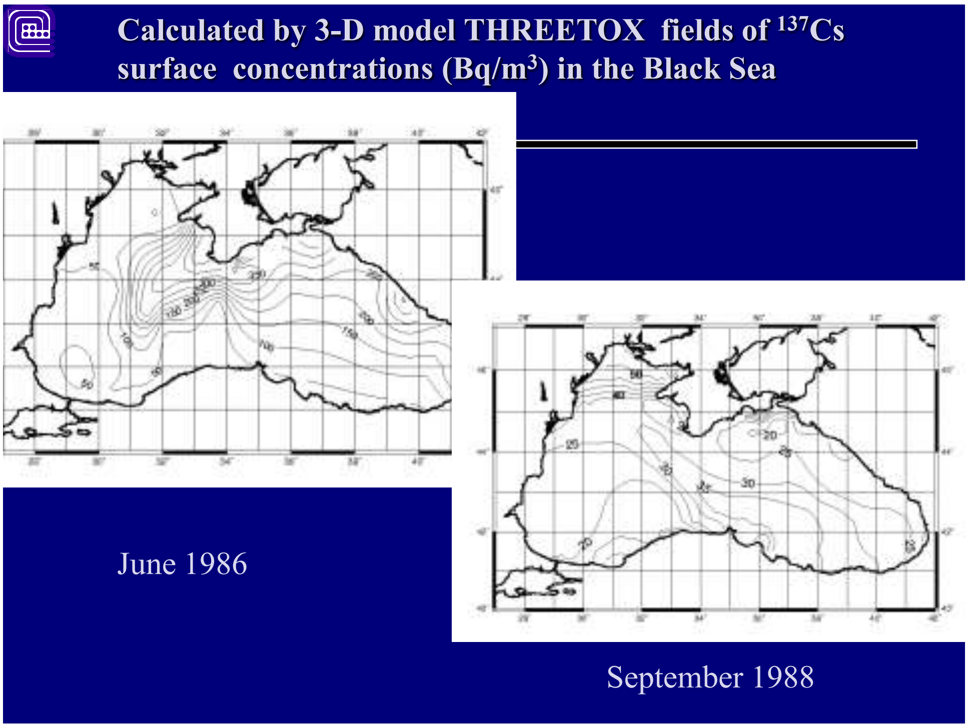




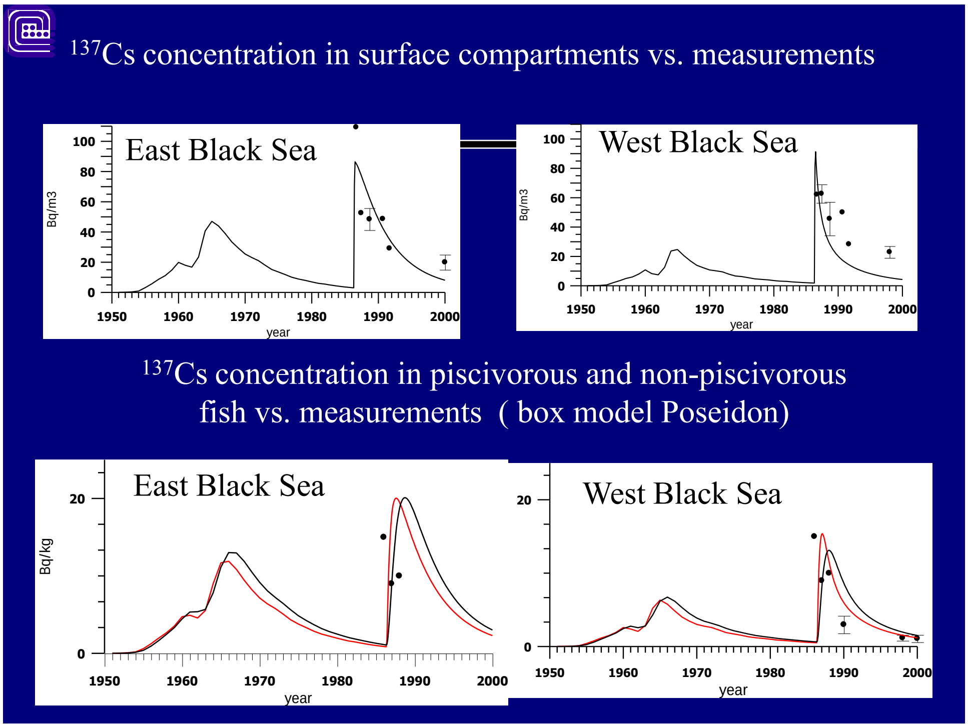
We apply three-dimensional model; different situation in the fluxes of cesium and strontium. Cesium, we have below zero flux to sea. It's flux to the sea of the cesium left and strontium right.

In principle, we have flux to the sea only in 1996, as for the cesium, because cesium, as I told you, is along this right 5 kilometer deep it's interacting with sediments. But for strontium, the maximum floods we have not in 1990. Here is the flux, first of all, from the fallout, atmospheric fallout. But interesting that for strontium we have maximum fluxes in 1997, why, because we have very long – many reservoirs and contaminated water from Chernobyl area, that arrived to the Black Sea only near 1 year later – 8 months later. We have experienced now with coastal area hydrodynamics. We have also interest to apply our models for marine transport of radionuclides in the coastal zone.

Coastal zone has very complicated hydrodynamics, because it's interaction between the currents and waves. We could calculate a lot of currents.



As for the Black Sea, here’s a picture in 1986 and 1988, how to change concentration in the sea.



You see now so for box model concentration of cesium, but you see that's interesting. In the East Black Sea, we have two pics. This pic is Chernobyl. Do you know what is specific? What is this?

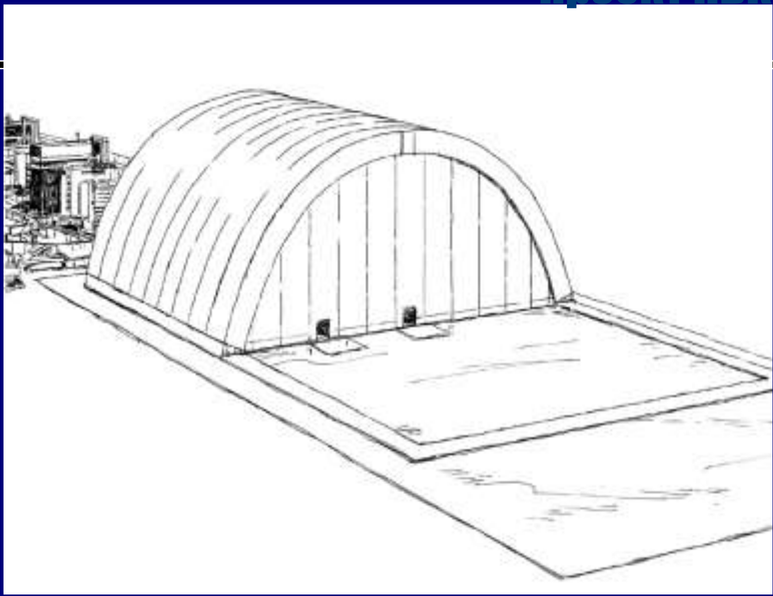
Do you know? It's bomb testing. Do you know that Soviet Union and the United States provided testing of more and more powerful [Unclear] bomb? The peak of this testing was here in the end of the 60s. At this moment, was signed the treaty to stop this. We see the Black Sea is very far from the [Unclear] Island where Russia provided testing from the French [Unclear] atoll. As I told that the United States provided testing of the bomb, but we could very clearly see contamination in the water, now in the sediments in this period. This is peak of the Chernobyl.

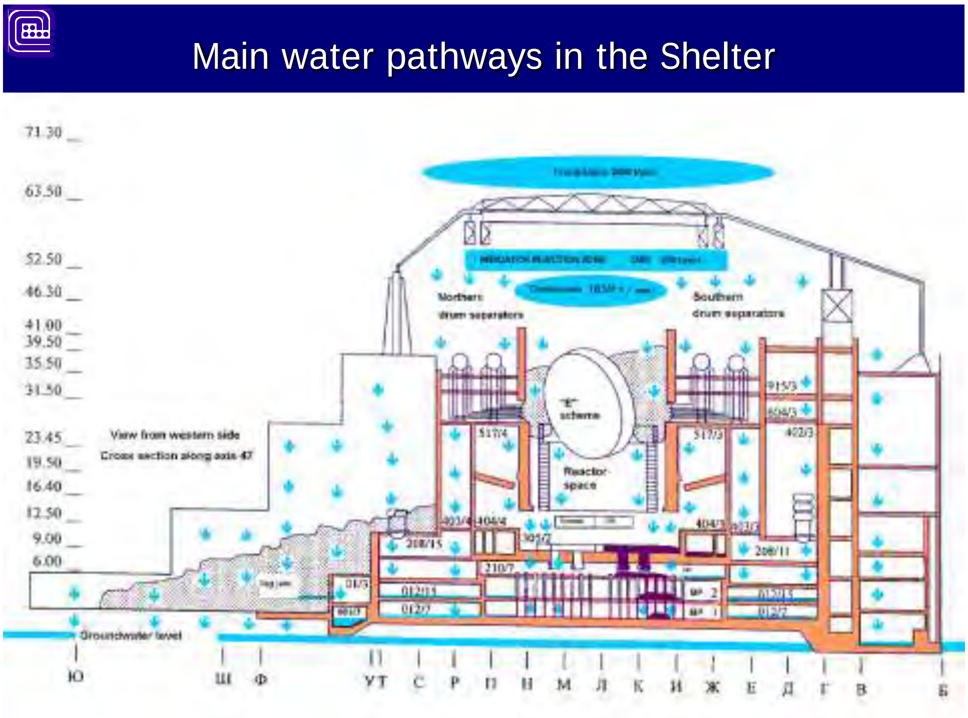
Also we have model to simulate concentration of the fish, also [Unclear] in the fish is the same, first peak and second peak,

Therefore, it was some kind of the barter. European Commission or community pressed Ukraine to shut down nuclear power plant in Chernobyl, energy production. At the same time, they proposed if you will shut down nuclear power plant, we will give you money to construct new shelter. It was a deal.

Ukraine shut down the reactors and we received from the donors near $1 billion for such kind of construction. It will be constructed nearby and then move above the shelter. Why such way of construction? Because it's dangerous today to look here above the roof and, therefore, to diminish the doses we should work a little bit, as I said. The first phase of principle design, it was a consortium of three organizations, it was a design of electricity [Unclear] is there, American company, but it's a nuclear power construction company in Pacific Northwest Laboratory.

Проект НБК

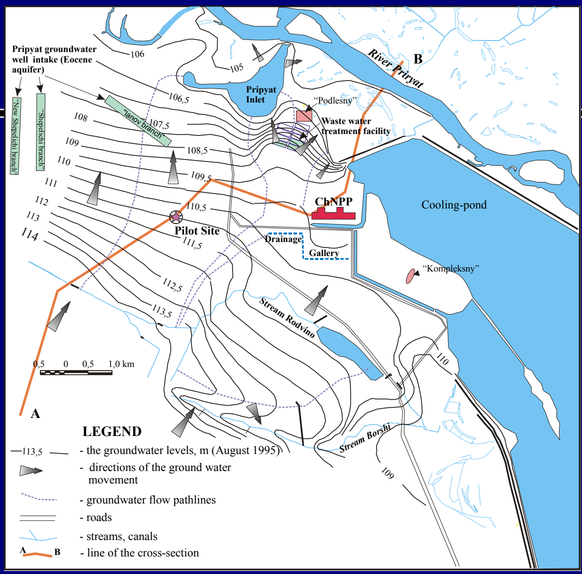




and especially Chernobyl now. It's now scheme [Unclear] now looks shelter. The shelter was constructed in 1986. Of course at this moment, it was very high level of radioactivity here. It was impossible to construct it very carefully and it takes 25 years [Unclear]. There're some holes in the roof and water penetrated inside. This water penetrated inside destroyed cover of the reactor. You see here this fuel part, fuel masses; it looks as glasses – as leaking glass. But in any case, water comes to these levels and this water, of course, is very contaminated.

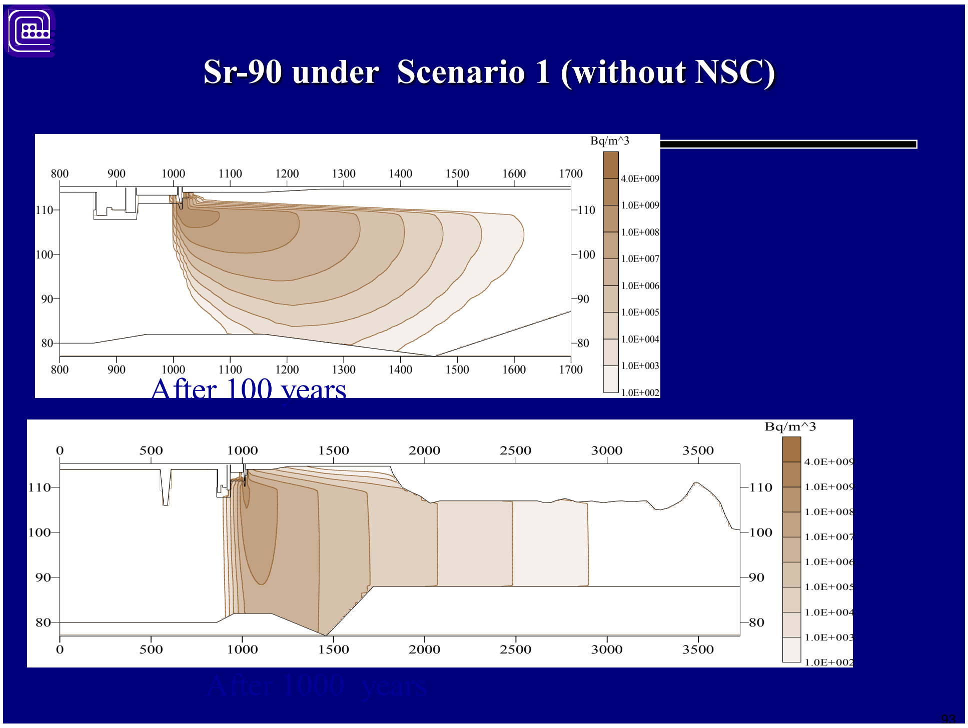
Today, it's impossible for people to come to this level, it's a few seconds, not more. Therefore, people are afraid about penetration of radioactivity to the ground, to the contamination of the groundwater, and one of the reasons of the construction was to prevent this water propagation. It's first.

Second reason, construction is old. In our area sometimes there could be also earthquake, not in Ukraine, but the closest source of earthquake is Romania, so it could be earthquake not high but up to the magnitude four. It could be some other elements. People are afraid that it could be distraction of this shelter, because it's not in good shape.



Groundwater levels of unconfined aquifer and groundflow direction in the ChNPP Near Zone

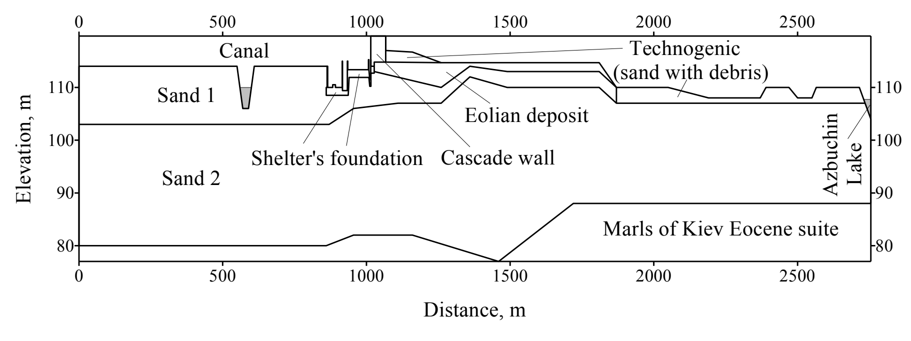
I was invited in the team of the Pacific Northwest Laboratory by Yasuo Onishi together with the lab to work on the DIA [ph], it's now a part of assessment for this one, and part of this DIA, and our team will not only provide modeling of the surface water, we will also provide modeling for the ground. The nuclear power plant is here. If we say that it's propagation of contamination to the bottom, to the soil, it could be after that propagated to the river. The task was to provide assessment.



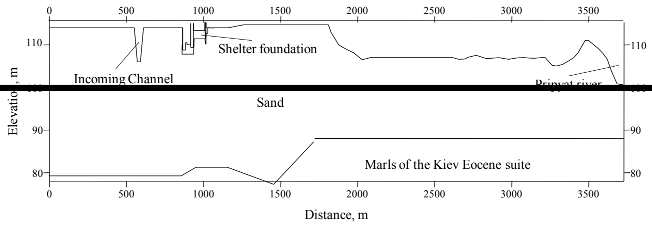
What will be the rate of this penetration and how quickly it will come to the river and in which amount? We say [Unclear].

The result was zero practically due to the very slow processes of the ground water and due to the absorption in the soil matrix.

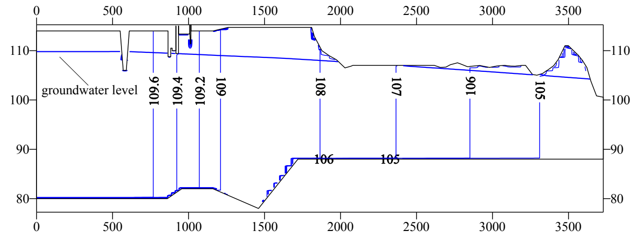
Schematic representation of geologic section



We demonstrate that contamination would come to this cross-section to the river, this water level, a simulation after 100 years, 1000 years.

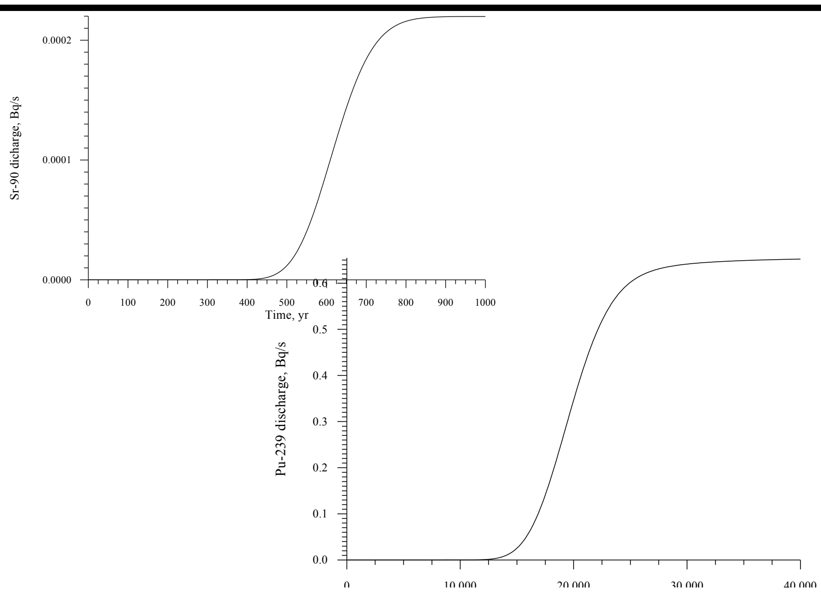


Geologic vertical section along the Shelter to the river



Water head distribution

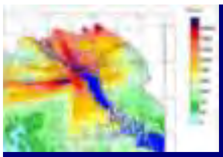
^{90}Sr and ^{239}Pu discharges from the Shelter into the Pripyat river via groundwater.



We demonstrated it will take from 400 years to 600 years to propagate to the river. Therefore, it was interesting situation. Why they should use $1 billion to construct the second shelter?

Because ground water is not [Unclear], even if you will have fall down of this shelter, the atmospheric dispersion could not be significantly dispersed, only few kilometers inside the Chernobyl zone, not to the populated area. But it's a reasonable countermeasure, because it could happen if tomorrow something will happen to the shelter, and people know that it will fall down, it will be such finding in Kiev that consequences of this finding is much, much higher than radioactivity. The flow and we see that as a psychological measure to protect, to make population feeling of the safety. It's necessary to do this. Now, it's just under construction.

Chernobyl Cooling Pond



Chernobyl Cooling Pond (CPP)

Since its completion in 1982, the pond covers an area of approximately 23 km^2 and contains approximately 149 million m^3 of water.

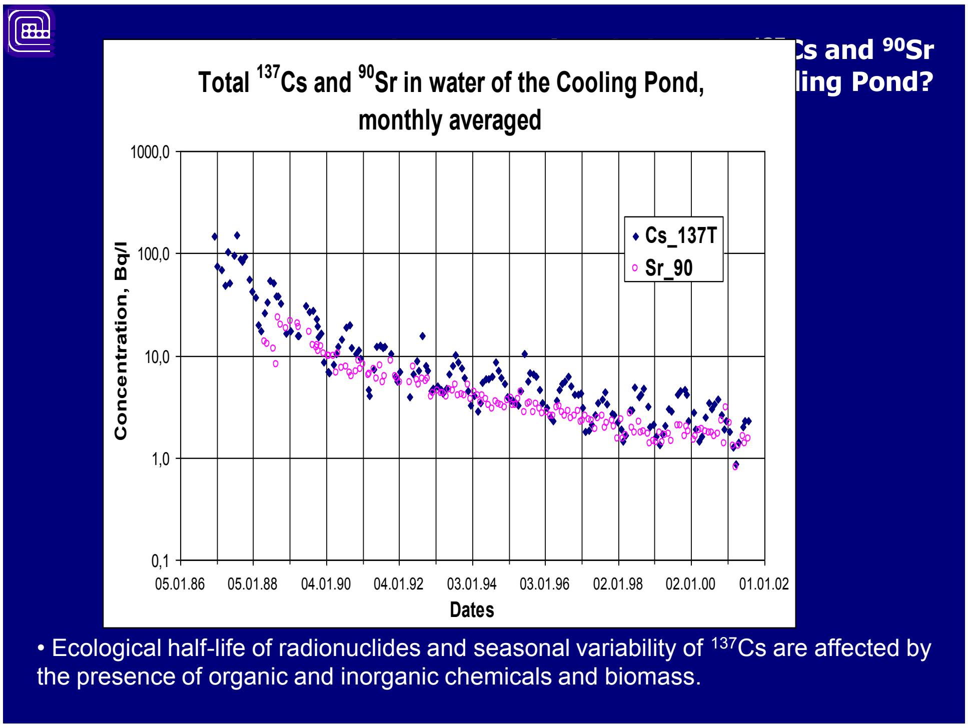
Mainly dispersed fuel particles settled on the water surface.

Heavily contaminated water (~5,000 m3) from the reactor basement released to the CPP

Heavily contaminated soils removed from the nearby sites dumped into the CPP

Long-lived radionuclides in the sediments:

170 TBq ^{137}Cs,
35 TBq ^{90}Sr and
0.8 TBq $^{239,240}Pu$.

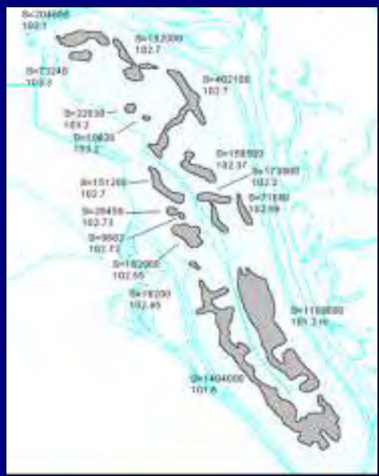


Next few words about the behavior of cesium and strontium. Here's a picture of the dynamic dam in this cooling pond of cesium and strontium. You could see a clear difference. If strontium, it's trend, such kind of trend. For cesium, you will see such variations. We applied [Unclear] model and drafted it.

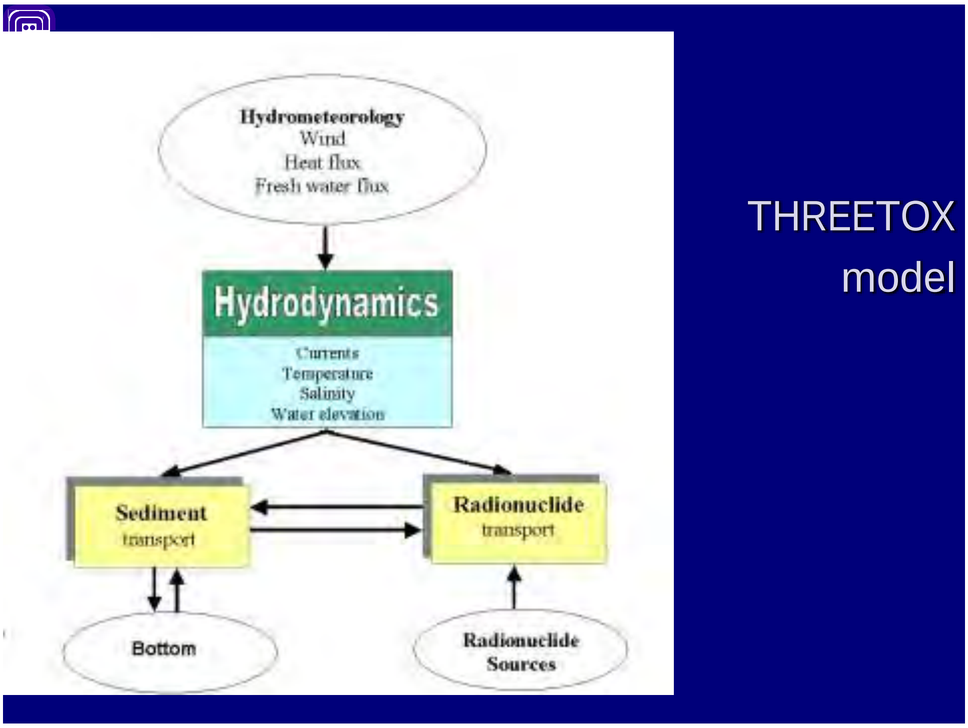
Why studies of sediment – water exchange mechanisms are so important for CPP?-

Due to the water level draw down at nearest years

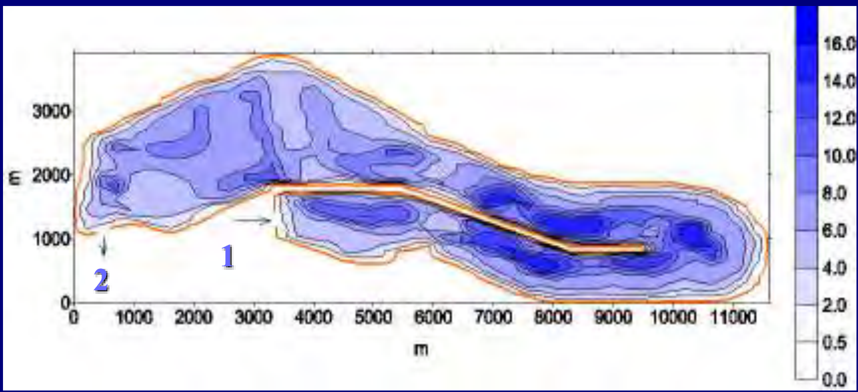
Normal scenario



Dry Scenario


Hydrometeorology
Wind
Heat flux
Fresh water flux
Hydrodynamics
Currents
Temperature
Salinity
Water elevation
Sediment
transport
Radionuclide
transport
Bottom
Radionuclide
Sources
THREETOX
model

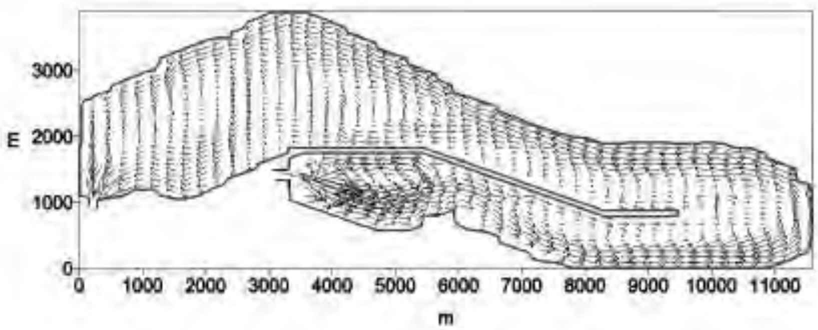
Bathymetry of the Chernobyl Cooling Pond



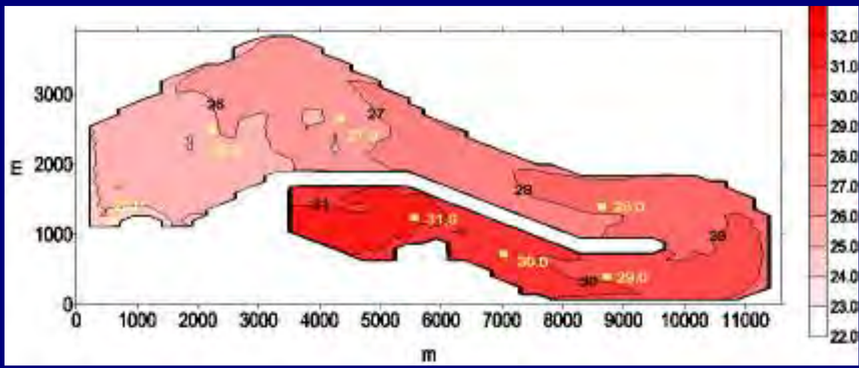
1- Channel of the hot water release

2- Water intake channel

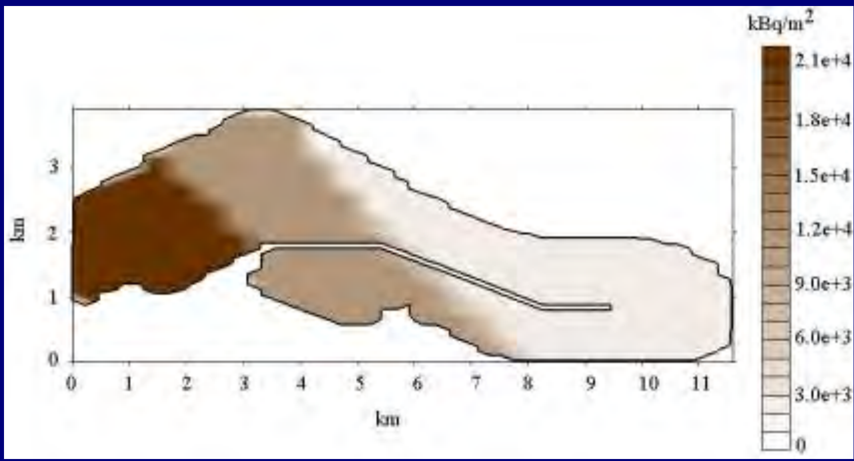
Surface velocity
Q=167 cub. m/s, |U|max=39 cm/s

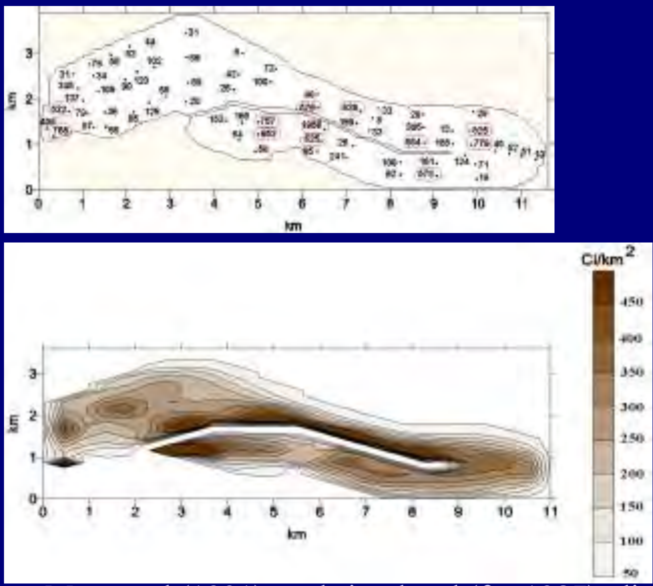


Simulated (red) and measured (yellow) water surface temperature (for 18.07.83)

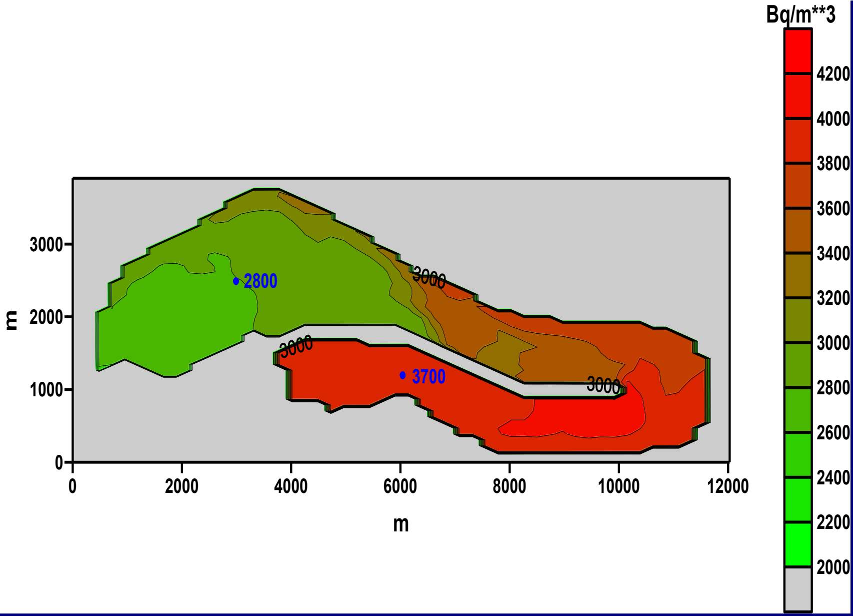


Fallout of ^{137}Cs at the surface of Cooling Pond of CPP in April 1986

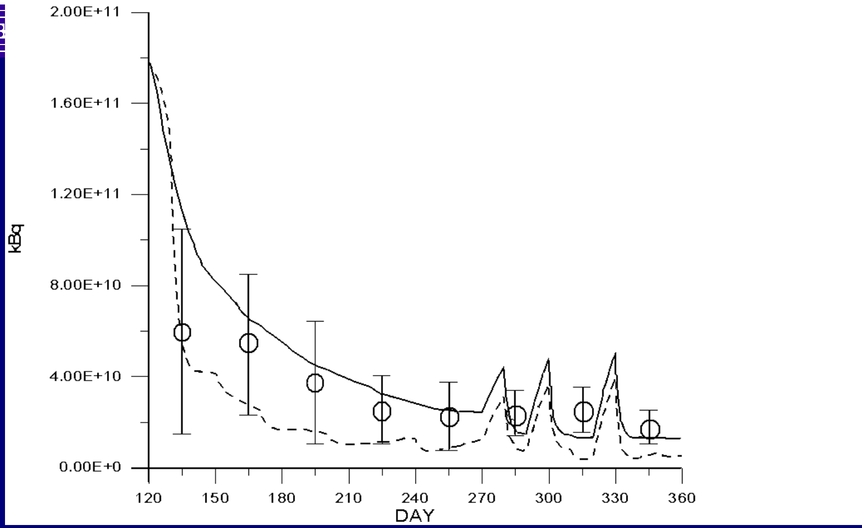




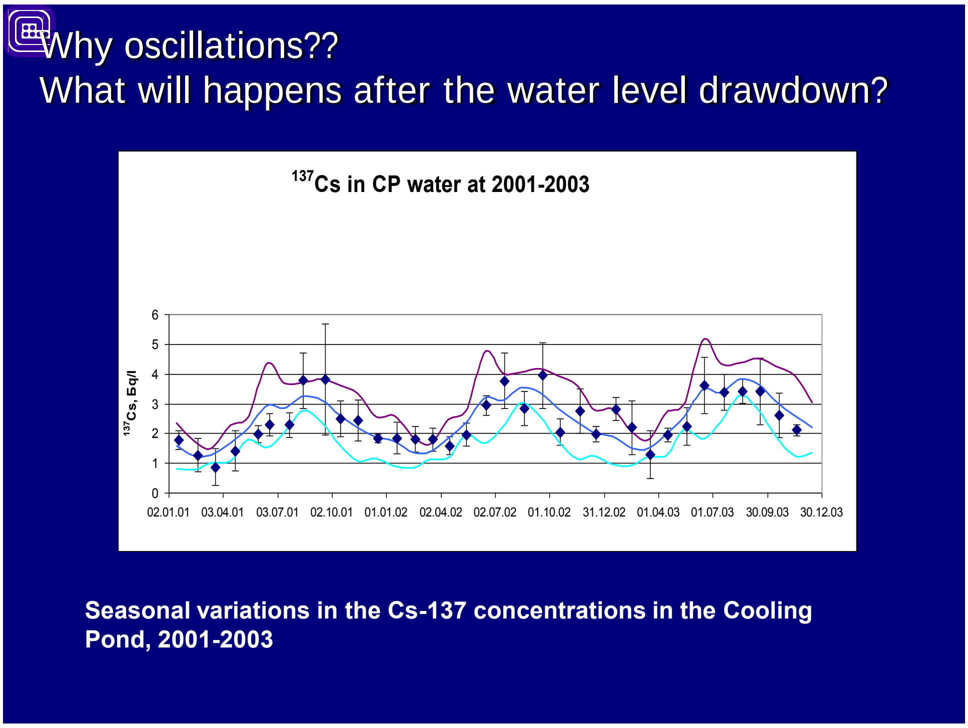
Measured (1991) and simulated (for 1987) distribution of ^{137}Cs in the bottom sediments of CPP



Simulated and Measured ^{137}Cs Concentration in Water (October 2003)



Simulated and measured dynamics of the ^{137}Cs content in the water column of CPP. Solid line: K_d = 3 m^3/kg, dashed line is K_d=15 m^3/кg.



Now, it's more clear here, more detailed periods from 2001 to 2003 and see this seasonal variation of the cesium. What is the reason for this variation? Because in principle, it's of course water body, not any floods, all time only some wind currents, but very clear year per year we have this oscillation of cesium in the water.

The formulae, connecting distribution coefficient Kd with the water ecological parameters and characteristics of the sediments (Konoplev et al, 1998,2002):

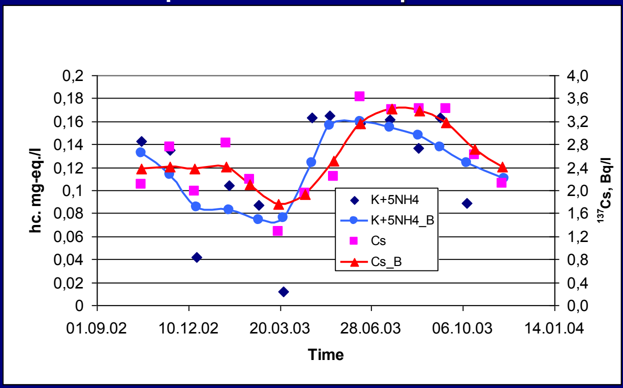
$$K_d = \frac{RIP}{[K] + K_c(NH_4/K)[NH_4]}$$

RIP – constant of sorbent;
[K] – potassium concentration, mg-eq/l;
$[NH_4]$ – ammonium concentration, mg-eq/l;
Kc(NH4/K) – selectivity coefficient, which value for CP could be estimate as = 5 (ESP3 Report) .
The parameter
h_c = [K]+5[NH4]
will be used as "hydrochemical potential".
Then Kd= RIP/h_c

After the Chernobyl accident, maybe the major progress was in the study of the physical-chemical of the multi-faceted interaction of cesium between sediments and water.

One of the set of such studies provided by Russian analytical chemist from [Unclear] and also [Unclear] from Belgium with some other people. They found their formula that connects Kd calculation, this very important distribution of calculation, with what you call it, with concentration of potassium and concentration of ammonium. They said that now it's not necessary to calculate, to measure Kd in each water body. We could pre-calculate it. If we know simple water quality [Unclear], if we know potassium concentration and ammonium concentration, we could predict value of Kd. We apply such approach.

Comparison of of ^{137}Cs concentration and "hydrochemical potential" temporal variations



Measured data and fitting curves

Temporal variation of potassium and ammonium concentration is driving force for ^{137}Cs oscillations in water. Can we simulate this phenomenon??

Here, you see the comparison of the concentration of cesium and the time shifts between the oscillation of cesium and oscillation of this blue line is start of [Unclear] concentration of potassium and ammonium. We see some time shifts between these peaks.

The dynamics of ^{137}Cs water- bottom exchange in water column is is described by following system of equations

$$\frac{dC}{dt} = -a_{1,3}(K_b C - C^b)\frac{\rho(1-\varepsilon)z^*}{h} - \lambda C$$

$$\frac{dC^b}{dt} = a_{3,1}(K_b C - C^b) - \lambda C^b$$

here

C **is radionuclide concentration in solution (Bq/m^3),**

C^b **is radionuclide concentration in bottom depositions (Bq/kg),**

$a_{1,3}$ **is sorption rate in "water-bottom deposition" system (sec^{-1}),**

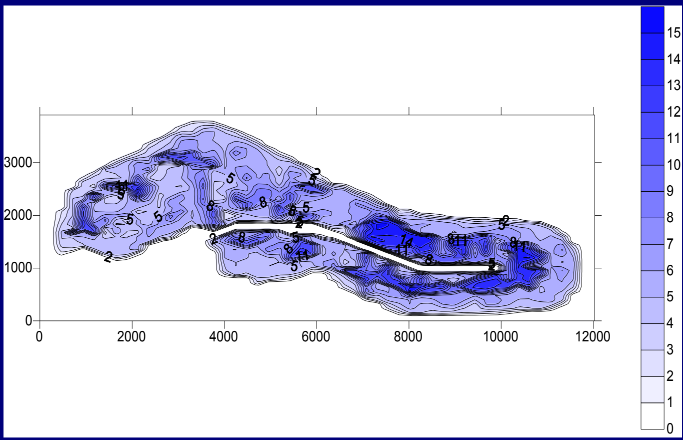
$a_{3,1}$ **is desorption rate in "water-bottom deposition" system (sec^{-1}),**

K_b **is distribution coefficient in "water-bottom deposition" system (m^3/k**

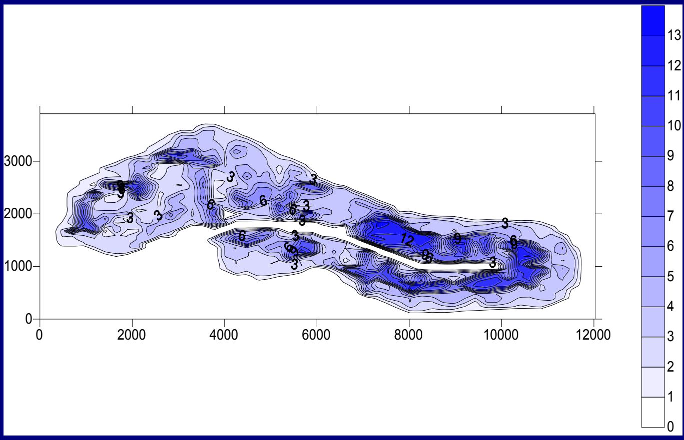
λ **is decay coefficient (sec^{-1}), ρ is denthity of bottom deposition (kg),**

ε is porosity coefficient, h **is water body depth (m).**

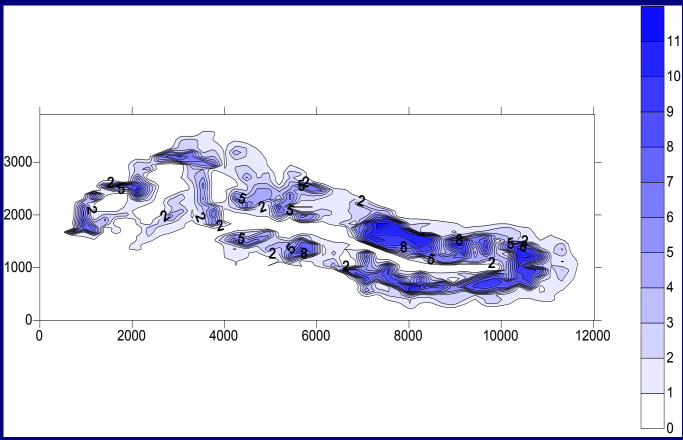
Pond bathymetry for contemporary water level



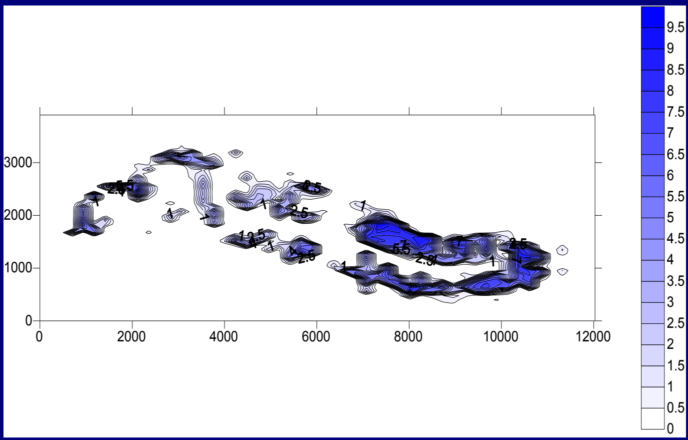
Pond bathymetry – water draw down - 2 m

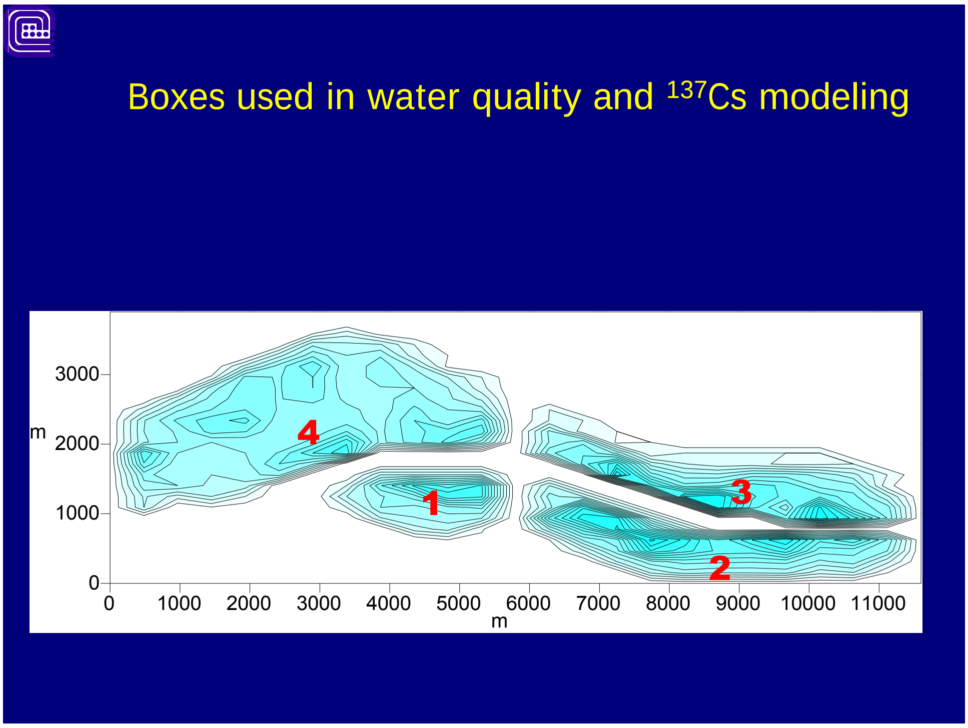


Pond bathymetry – water draw down - 4 m

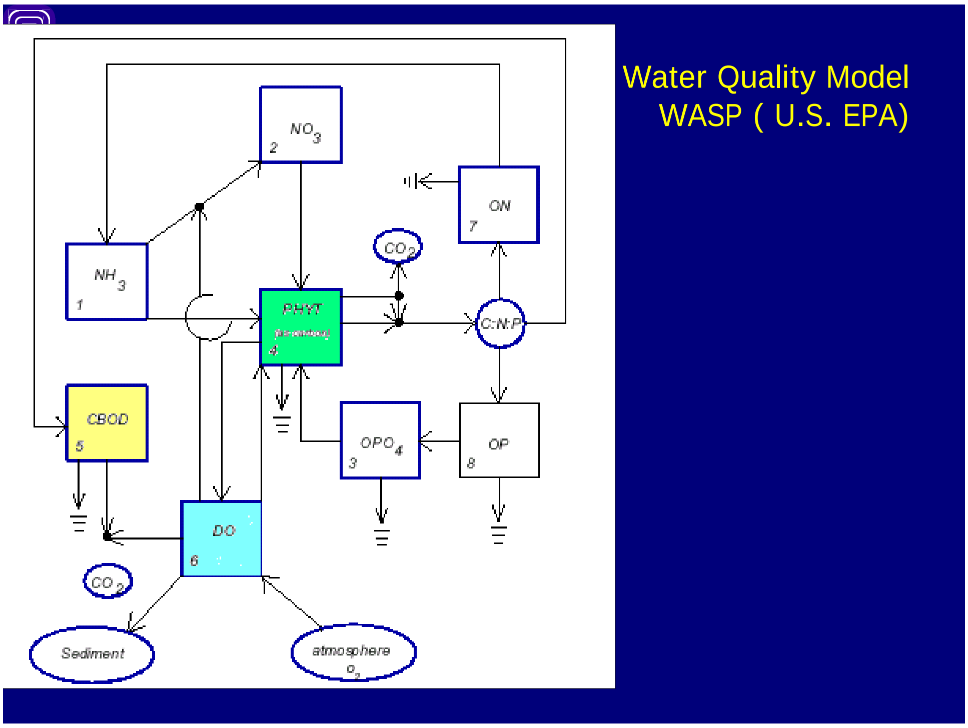


Pond bathymetry – water draw down - 6 m



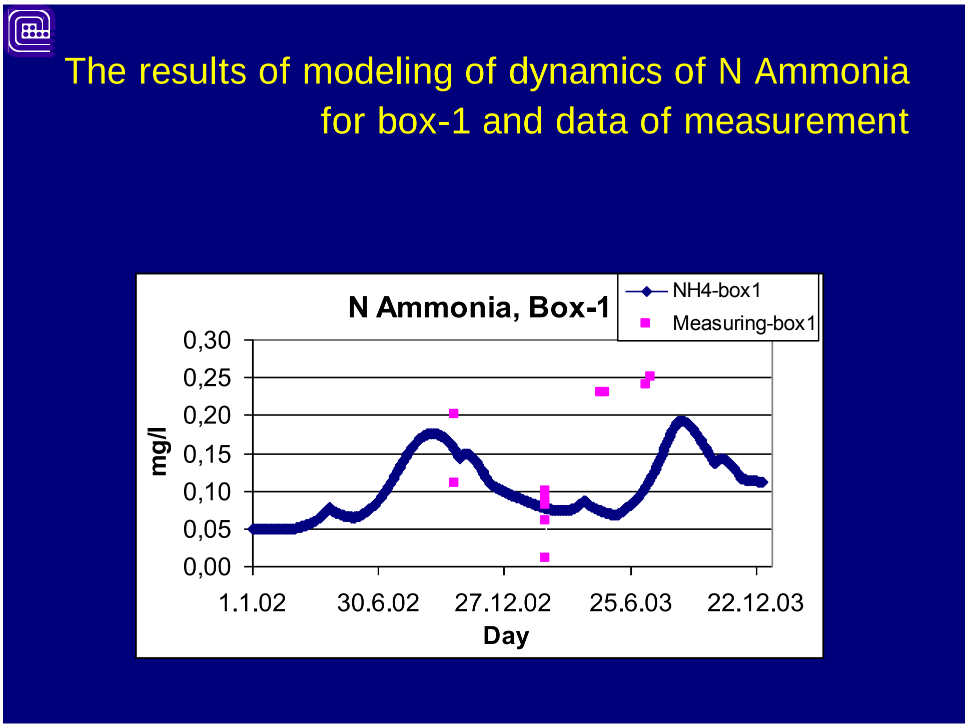


We apply the same model that I demonstrated to you, but now we apply Kd, not permanent value but value depending on time. We demonstrated in this case, it could be analyzed situation in four boxes for part of this reservoir.



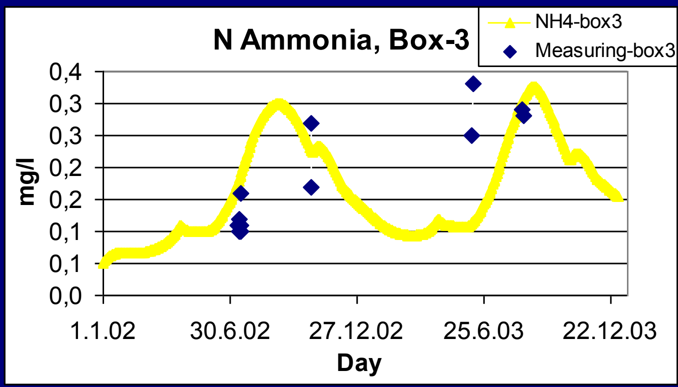
We use American model for water quality. That could be described dissolved oxygen, also phytoplankton concentration. Why it happened in the lake? We have cold winter and, in principle, all small biota died.

But after that in the spring, it's started to be growth of the algae, phytoplankton. They produced this ammonium to the autumn. But after autumn, cold and it died. Each year, we have the cycle of the water chemical parameters. You see that these water chemical parameters – they provide an impact on the concentration of radionuclides,

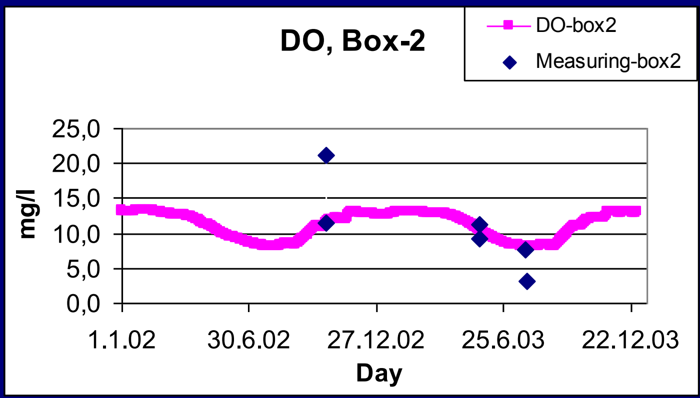


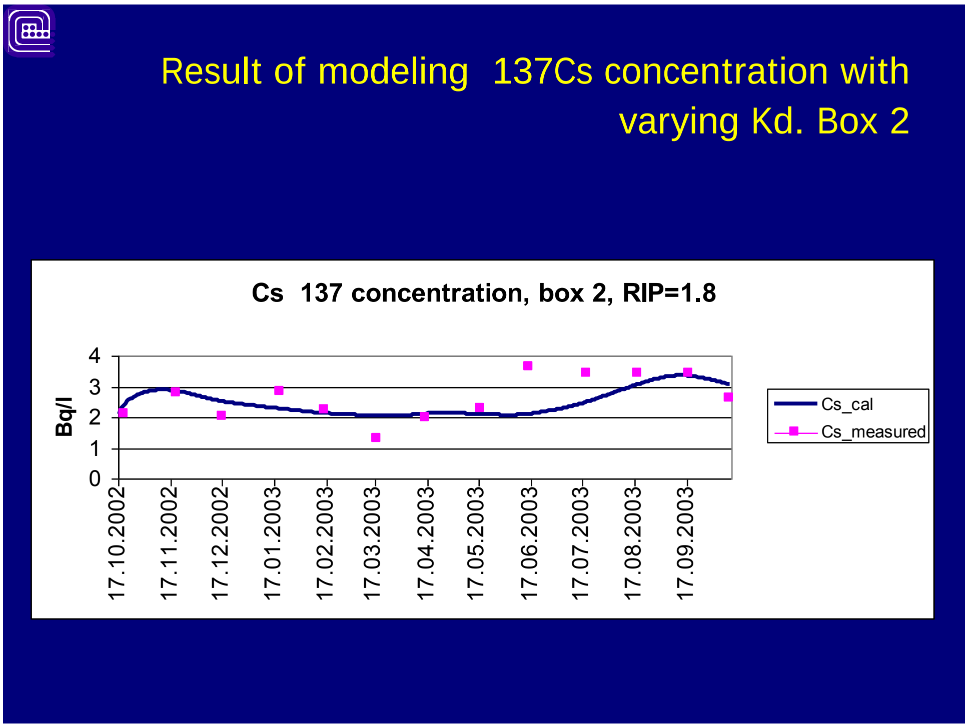
so we test this model for simulation of ammonium. We compare this model result with real measurement of water quality.

The results of modeling of dynamics of N Ammonia for box-3 and data of measurement



The results of modeling of dynamics of DO for box-2 and data of measurement



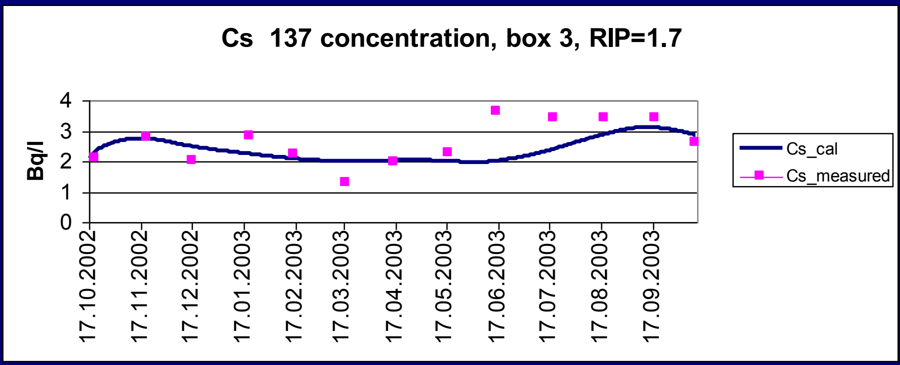


Then, we demonstrated our simple model. This could produce this oscillation in radionuclides. Why it's important? It's not only because we study this, because it's important for [Unclear].

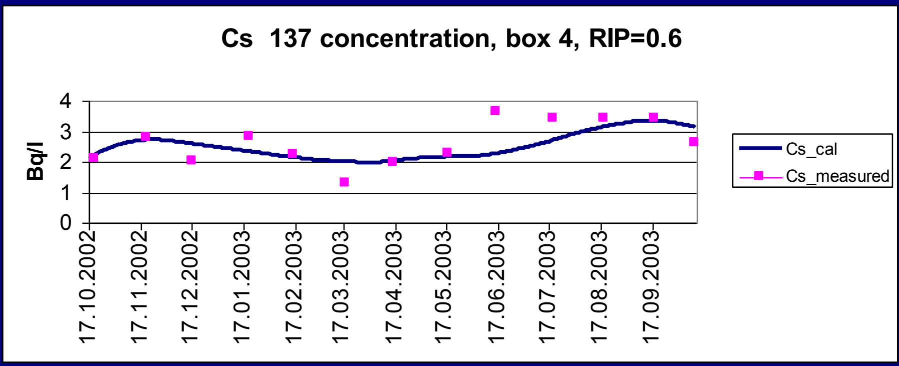
People asked us, okay, now we stop this [Unclear], water level in this cooling pond will diminish. Please answer. What happened in this case in the concentration of cesium in the small lakes? Because it is very big water body. Now, it will be a set of small water bodies. Now, we have more concentration today in this big water body. What is the concentration of the small water bodies? We could not answer two the same, because smaller water body and another amount of – another temperature, it will be more warm.

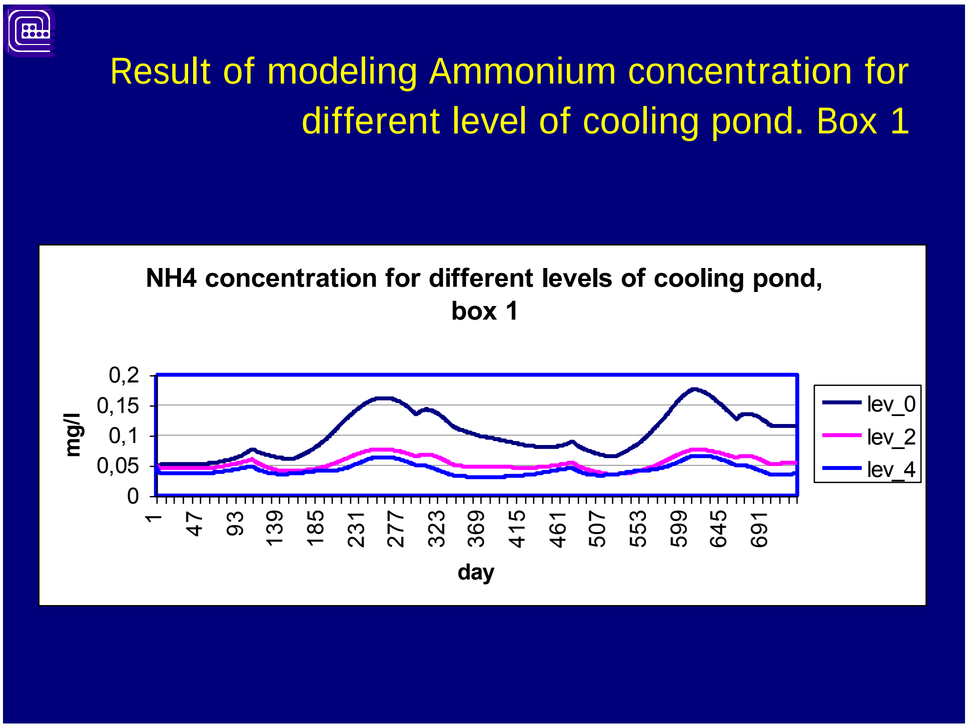
Another amount of phytoplankton, another concentration of ammonium and potentially another concentration of the – for the – not theoretical studies, now theoretical is model, but in the same time it acts on the particle [Unclear]. Therefore, we now provide such modeling.

Result of modeling 137Cs concentration with varying Kd. Box 3



Result of modeling 137Cs concentration with varying Kd. Box 4

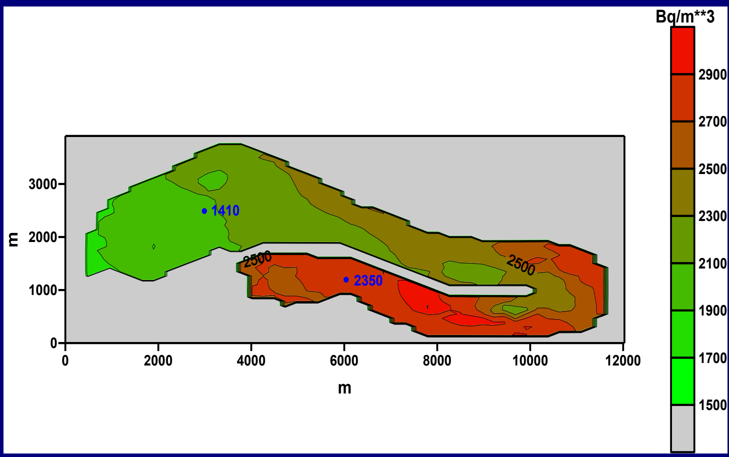




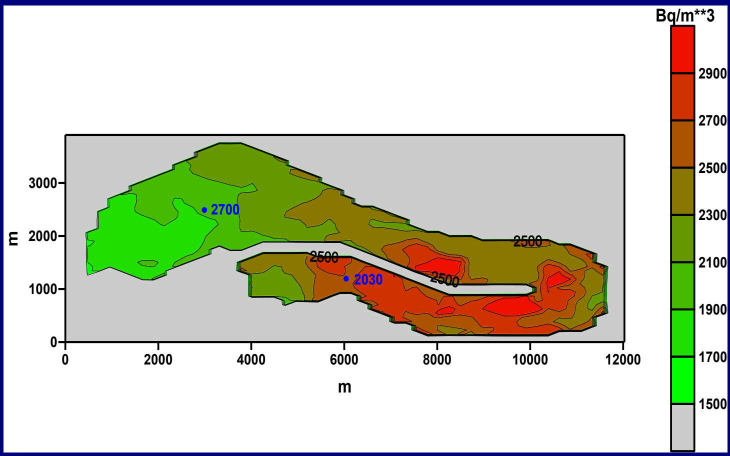
We simulate concentration of these boxes for different levels and try to answer what happens.

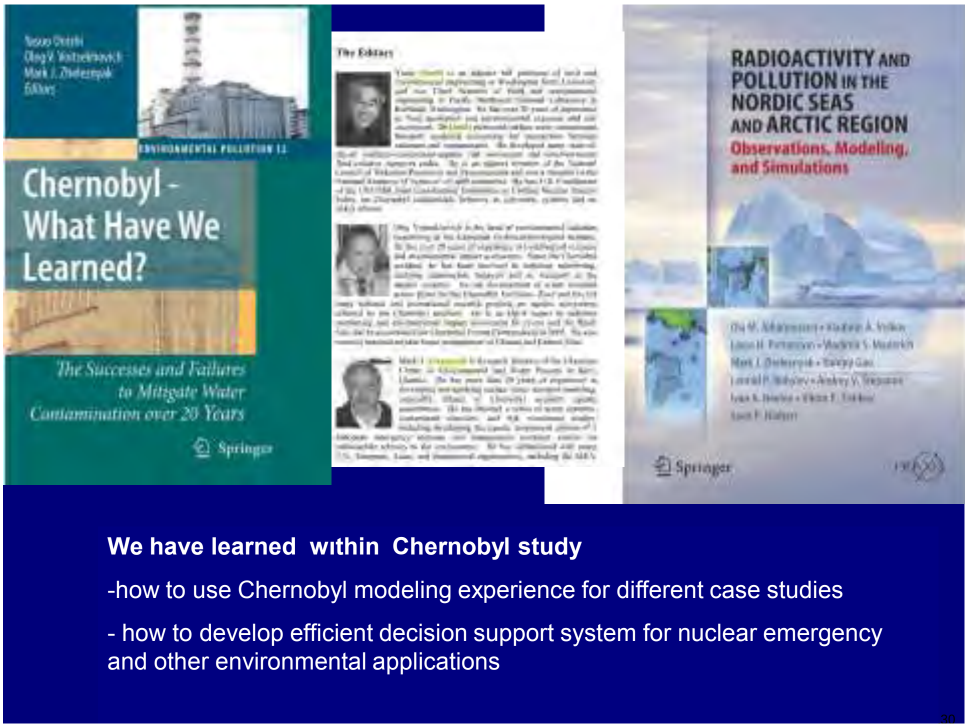
Three-dimensional dynamics of 137 Cs in the Cooling Pond for different water levels

Consentration dissolved Cs-137 near the surface and comparison with measurement (May, Level 0)

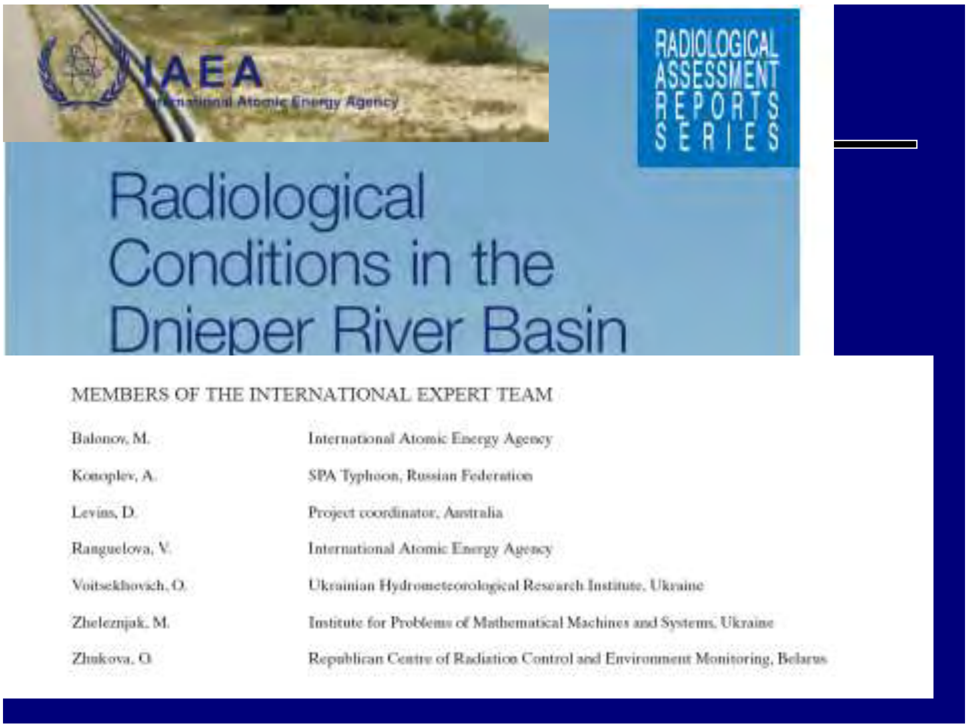


Consentration dissolved Cs-137 near the bottom and comparison with measurement (May, Level 0)

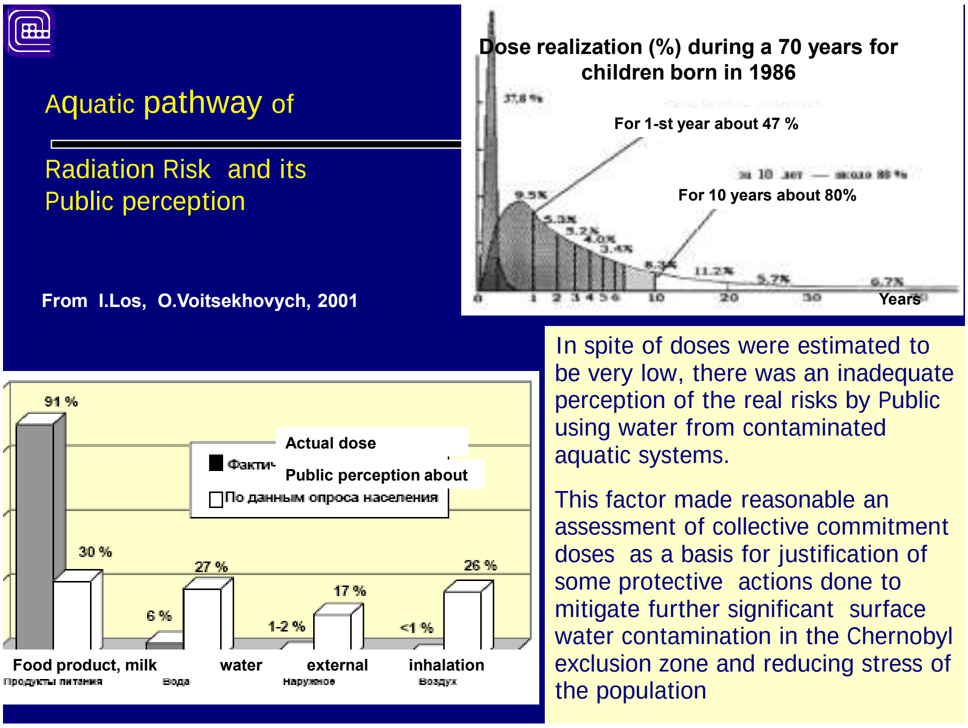




We also apply two-dimensional model for this. Through our publications, our results have been published in this book.
This was edited by Yasuo Onishi. I mentioned several times his name. By me and by Oleg Voitsekhovych who was responsible for monitoring data. Title is Successes and Failures to Mitigate Water Contamination over 20 years.



Also, information about Dnieper River contamination was send a copy of this report to IAEA that you should [Unclear] mentioned as professional physical-chemical [Unclear].



Now, I will say a few words about [Unclear] title about the countermeasures because I would like to explain you methodology. This example will be of dikes. We demonstrated applying these dikes that we diminished concentration of radionuclides, but question is what is the profit, because to see the real positive result we should be pleased to do this. We should calculate exposure of doses for population that could receive the doses from Dnieper River and how people achieve the doses. Even external, if person goes to the beach and the water is contaminated with the sediments, it will be external, but small.

Drinking during the swimming and major pathway through the irrigation, as water from the river is used for irrigation. It is contaminated. The [Unclear] product will be contaminated. In Ukraine, water from the Dnieper is used for the irrigation for the rice, for the wheat and other agriculture products in the south.

Long-term doses from aquatic pathways. **Summary**

Human exposure via the aquatic pathway was result of consumption of drinking water, fish catch in reservoirs and agricultural products grown using irrigation water from Dnieper reservoirs.

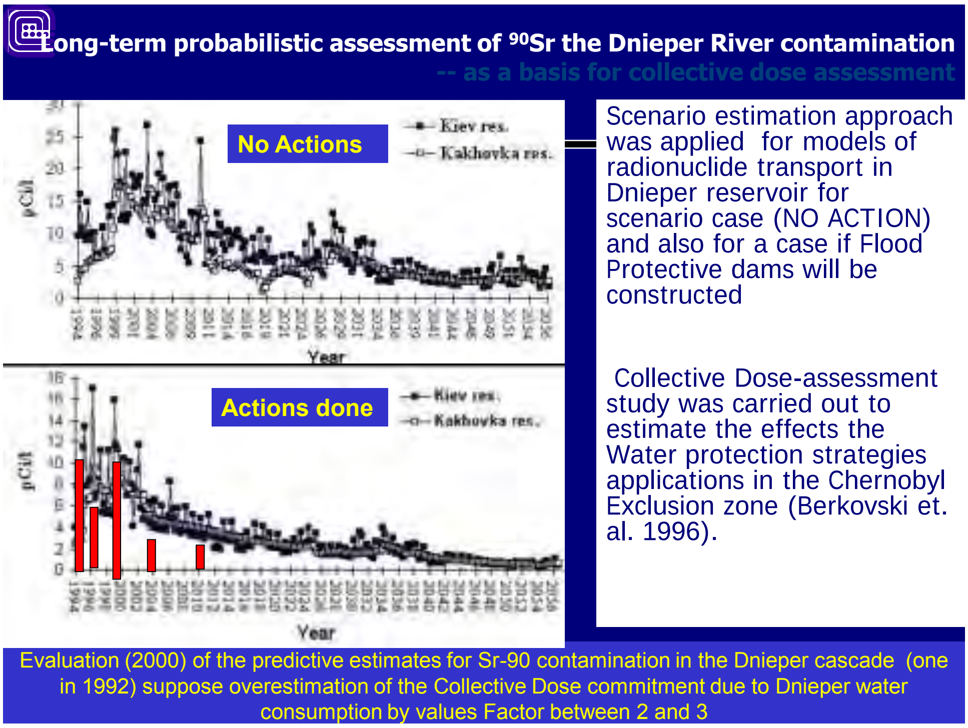
Estimates were that individual doses for population living along the Dnieper cascade through the aquatic pathways (far away from ChNPP affected area) did not exceed 10 μSv y^{-1}.

However, collective doses were estimated as rather high. No alternative water consumption. Stress component was dominated as a factor taken into consideration when the water protection actions planned.

Furthermore, in some closed lakes, the concentration of ^{137}Cs remains high and high levels of contamination are found in fish species. People who illegally catch and eat contaminated fish may receive internal doses in excess of 0,5-1 mSv per year from this source.

The most significant contribution to the individual doses from aquatic pathways caused by ^{131}I in the first week after the accident, but for very short time (Maximal values about 140 Bq/l observed at the Kiev water intake plant 30 04 1986).

We calculate the doses and I will talk about it.



As we calculated this impact of the dikes, we calculated the forecast for 70 years. If we construct dikes, what will be the reduction of the contamination and there will also be a reduction of the doses?

Collective dose commitment (CDC_{70}) to be caused by ^{90}Sr and ^{137}Cs in the Dnieper's reservoirs water, consuming by people in the different regions of Ukraine for a period of 70 years from 1986 to 2056 (Berkovsky et al. 1996)

Region	Population, (in millions of people)	^{90}Sr CDC_{70} (man-Sv)	^{137}Cs CDC_{70} (man-Sv)	Ratio ^{90}Sr CDC_{70} $(^{137}Cs\ CDC_{70})^{-1}$
Chernigov	1.4	4	2	2
Kiev	4.5	290	190	1.5
Cherkassy	1.5	115	50	2.3
Kirovograd	1.2	140	40	3.5
Poltava	1.7	130	60	2.2
Dnepropetrovsk	3.8	610	75	8
Zaporojie	2	320	35	9
Nikolaev	1.3	150	20	8
Kharkov	3.2	60	4	15
Lugansk	2.9	15	1	15
Donetsk	5.3	330	20	17
Kherson	1.2	100	20	5
Crimea	2.5	175	5	35
Total	32.5	2500	500	5

Dose estimates for the Dnieper system show that if there had been no action to reduce radionuclide fluxes to the river, the collective dose commitment for the population of Ukraine (mainly due to Cs and Sr) could have reached 3000 man Sv.

Protective measures, which were carried out during 1992–1993 on the left-bank flood plain of the Pripyat River and later on right bank (1999) have to result decrease of the exposure by approximately 1000 man Sv. (Voitsekhovich et al. 1996).

As a result of this calculation, it was calculated that in general from all over they take Dnieper water.

That goes through the aquatic pathway. It could be near 3000 man-sievert. But when we apply these dikes, we could diminish these doses. It will be 1000 man-sievert less. After that it was taken decision to construct the dikes, because we demonstrated in principle in international recommendation, they even provide the cost of the advertisements here. We said that after the accident, it was proposed very many countermeasures as example to construct special dikes, special troughs in the river. Such idea that if we know that half of cesium and even more is transported by the river water, let's construct the troughs, let's make in some places, river more deep and more wide.

Idea is that it will be a – velocity flow will fall down and as a result a fall down of the sediments, so these troughs will take sediments from the water flow and prevent propagation downstream. But even one such trough was constructed, but what we calculated it was also provided by experiments. Such traps will catch only larger sediments, but fine sediments are more contaminated than large sediments.

Therefore, then only small amount of the cesium will be trapped in such places. From other side, taking into account that this trap was constructed in the Chernobyl zone very close to the reactor, people who construct these traps was exposed to radioactivity. These doses, they receive during this [Unclear] wasn't compensated by the diminishing of dose to the population here.

About this theme that when you provide assessment of the efficiency of the countermeasures, the final criterion is not environmental pollution. Final criterion is doses that could be received by the population. We apply this approach.
From this approach, only this dike protected from the washing out from the sedimented territory could be – we considered it efficient.

Doses

3500 employees of ChNPP took part in the postaccidental works in 26 April – 31 December 1986. Their average individual dose is 97 mGy.

The average individual dose of 1600 people of the staff, working in NPP during the main release (April 26-30) is 406 mGy.

18 workers died of acute radiation sickness (the average individual dose is 625 mGy)

The collective dose for all 126000 liquidators of the acute post-accidental phase phase is about 40 000 man-Gy.

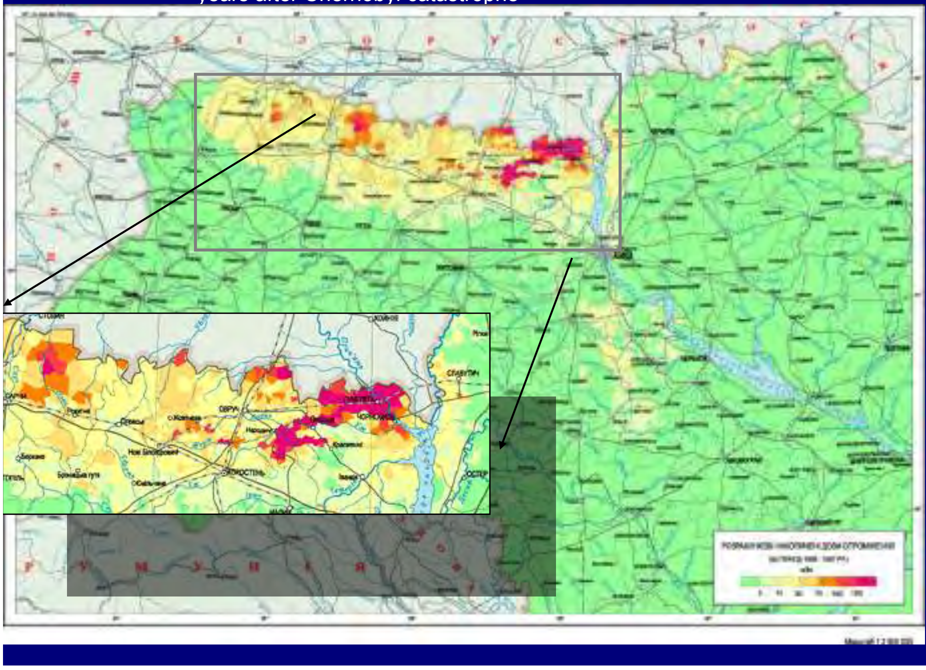
Doses (3)

The estimated accident collective effective dose to the population of the 2 zone was 481 man- Sv and 1280 man-Sv to population relocated from 3 zone

The collective effective dose to Ukrainian residents affected by the accident at ChNPP is 47,800 man-Sv for fifteen years (the exposure doses to thyroid from radionuclides of iodine are not taken into account.)

Over 95% of dose is produced by ^{137}Cs, the rest of 5% is due to ^{90}Sr with a share of a percent contributed by plutonium.

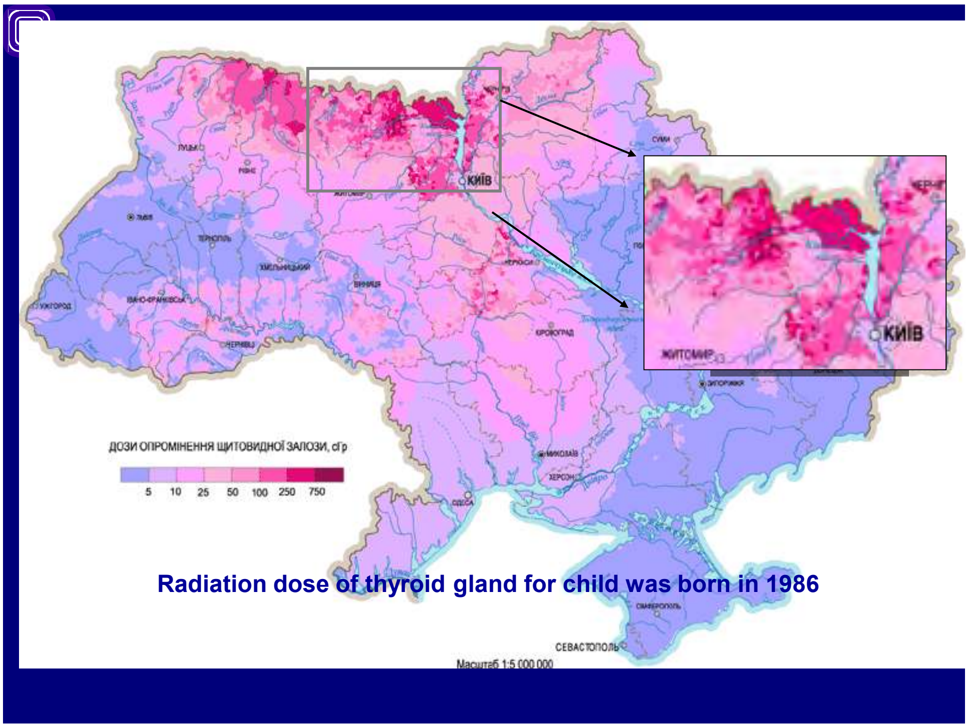
Total effective dozes of internal and external exposure for 70 years after Chernobyl catastrophe



Doses (4)

One of the most serious consequences of the Chornobyl accident to the health of Ukrainian people, and first of all for children, was the exposure to thyroid due to radioactive isotopes of iodine

The collective dose to thyroid of all children of Ukraine (under 18 at the moment of the accident) is estimated as 400 000 man-Gy .



Radiation dose of thyroid gland for child was born in 1986

Risk Assessment – Health Effects

The risk of cancer mortality for “liquidators” 1986-1987 is estimated as 1,3 10^{-2} .

For 126,000 liquidators it is risk of 1600 lethal cancer cases.

The risks of thyroid cancer are estimated:

8 cases of adults per 10,000 man-Gr

and

46 cases of children per 10,000 man-Gr.

The collective doses within fifteen years after the accident and estimated cancer mortality (thyroid not included)

Group of the affected population	Collective dose, man-Sv	Number of people	Expected amount of cases per 100,000	Total expected amount of cases
Population of Ukraine	47,800	49,000,000	5	2450
Individuals evacuated in 1986	1,300	89,000	73	65
People resettled since 1991 from the 2-nd and 3-rd zones of radioactive contamination	1,760	52,000	169	88
Participants of post-accidental works at ChNPP in 1986- 1987	40,000	126,000	1270	1600

The collective doses after the accident (on thyroid) and estimated risk of thyroid cancer

Group of the affected population	Collective dose, man-Gy	Number of people	Expected amount of cases per 100,000	Total expected amount of cases
All children of Ukraine in 1986	400,000	13,183,000	14	1840
Residents of most contaminated regions	191,000	497,000	31	153

6,685,600 forecast of cancer mortality in Ukraine for 70 years

Cancer mortality of population of Ukraine from all sources (statistical data 1999)

	Number of people	Cancer mortality per 100,000 per year	Amount of cases per year	Amount of cases per 100, 000 per 70 years	Total amount of expected cases per 70 years
Cancer mortality of population of Ukraine (all cases – registered mortality -1999)	49,000,000	192	94,080	13,440	6,685,600

Comparison of "Chernobyl" and "natural" cancer mortality

Group of the affected population		Number of people	Expected "natural " cancer mortality for 70 years	Expected additional "Chernobyl" cancer mortality
Population of Ukraine		49,000,000	6,685.600	2,450
Individuals evacuated in 1986		89,000	11,961	65
People resettled since 1991 from the 2-nd and 3-rd zones of radioactive contamination		52,000	6,988	88
Participants of post-accidental works at ChNPP in 1986- 1987		126,000	16,934	1,600

Mortality of Ukrainian population per year caused by different reasons

Mortality caused by	Cases per 100,000
All sources	1490
Cardiovascular system diseases	916
Cancer	194
Suicides	29.7
Occasional poisoning	25.1
Transport accidents	14
Murders	12.2
Chernobyl Radiation Risk Assessment.-cancer mortality	5/70=0.07

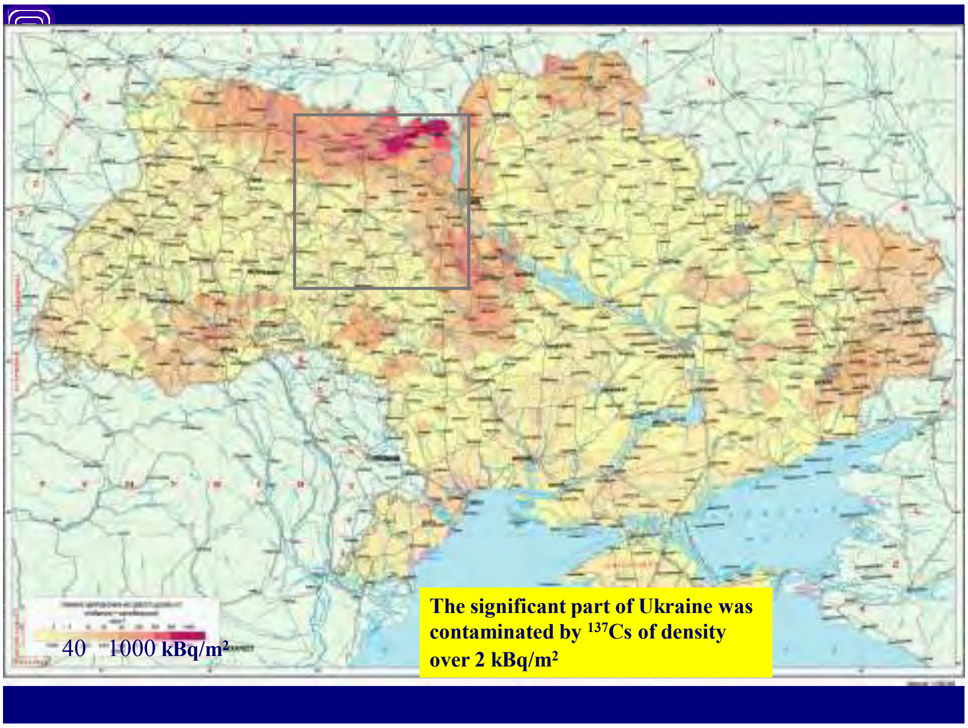
Cases per 100,000 – statistical data 1999 and Chernobyl risk assessment for 15 years dose

Comparison of Budget of Ministry of Chernobyl and Ministry of Public Health of Ukraine

Year and dimension of currency	Ministry of Public Health (1)	Ministry of Chernobyl (from 1996-MES) (2)	(1)/(2) %
2002 Mln of hrivna	1 415	2 300	62%
1999 Mln of Hrivna	580 634	1 746 800	33%
1996 Mlrd of karbovanets	56 207	179 455	31%
1993 Mln of karbovanets	104 723	611 300	17%

Due to the inflation only comparison of (1) and (2) for each year is important, not absolute values

Source of data: State budgets 1993-2002 taken from the web site of the Ukrainian Parliament



40 1000 kBq/m²
The significant part of Ukraine was contaminated by ¹³⁷Cs of density over 2 kBq/m²

National Institute of Cancer in Ukraine

Cancer in Ukraine
2008-2009

http://www.ucr.gs.com.ua/dovida8/index.htm

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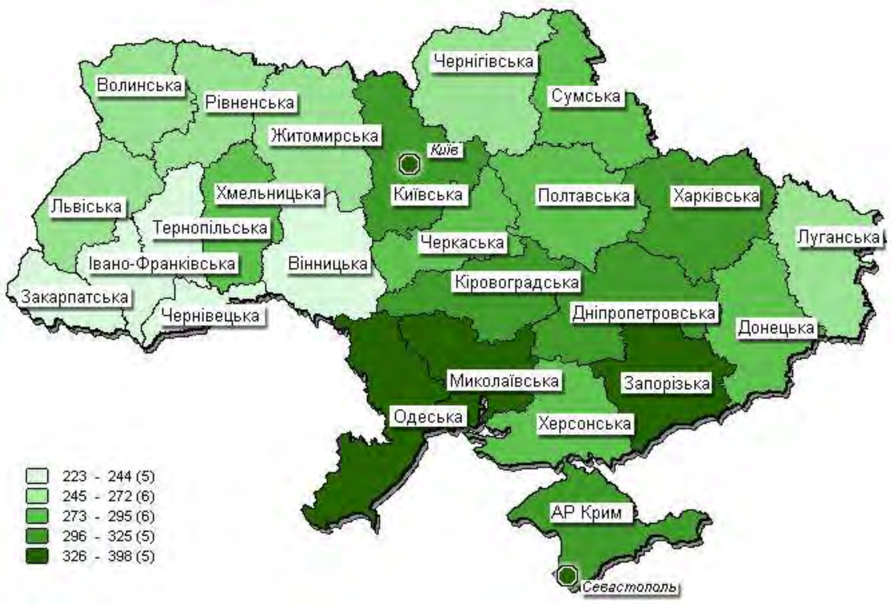
Захворюваність чоловіків на 100 тис населення (2008)

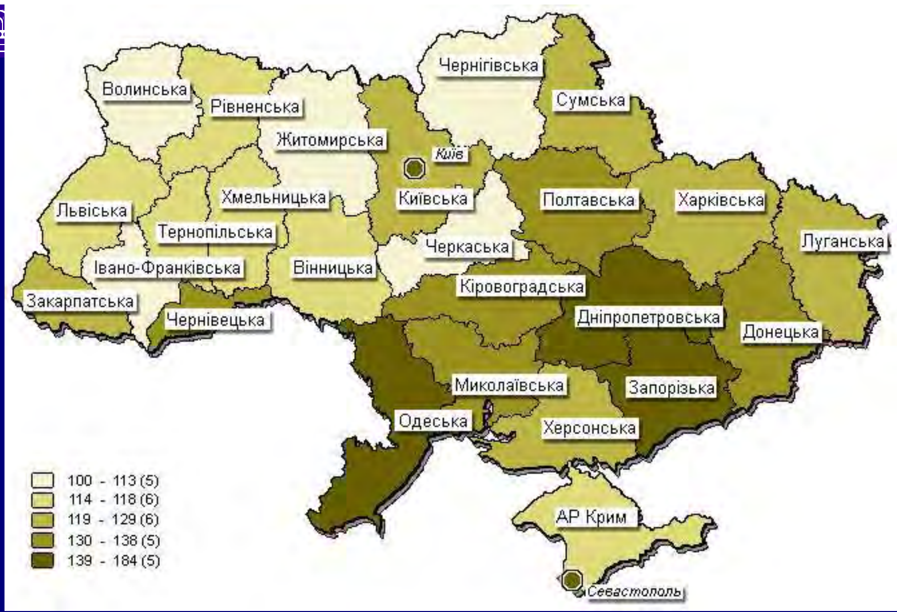
Cases of cancer per 100 000 of man (2008)



Захворюваність жінок на 100 тис населення (2008)

Cases of cancer per 100 000 of woman (2008)

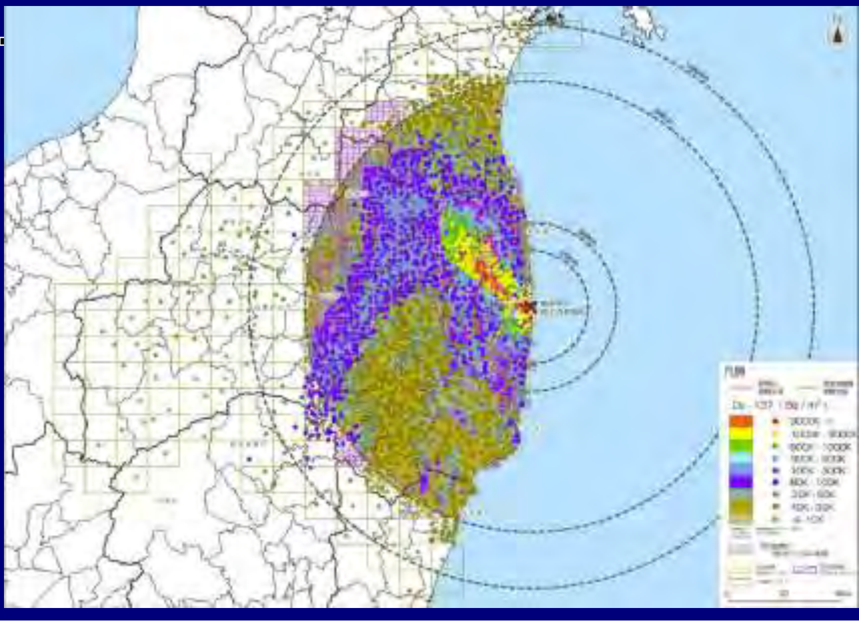
Смертність чоловічого населення від злоякісних утворень (2008)
Mortality from cancer per 100 000 man (2008)

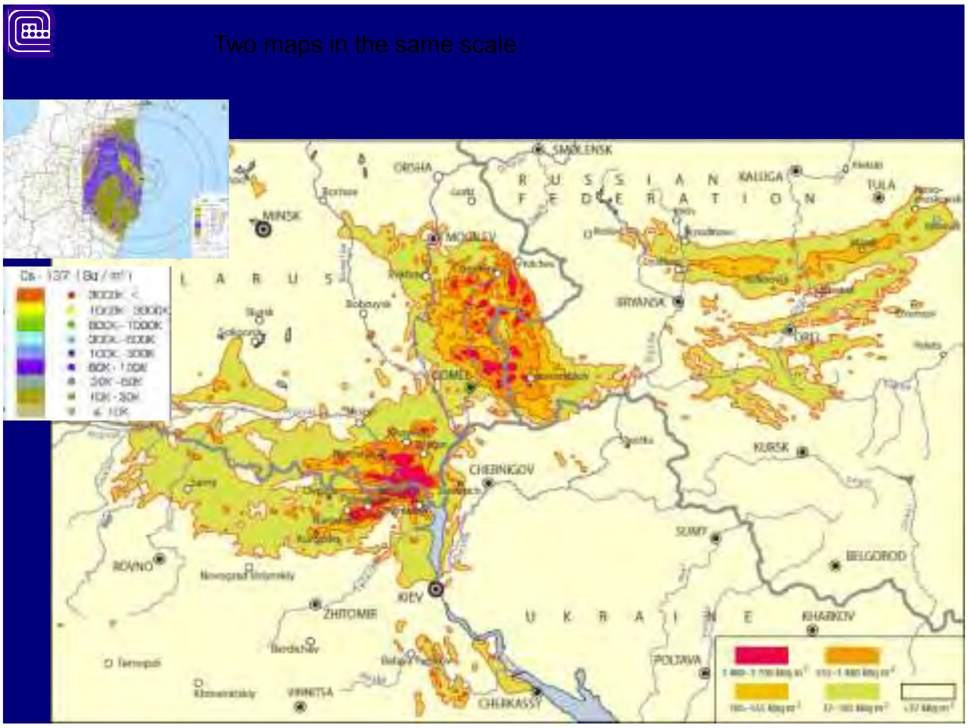


Смертність жіночого населення від злоякісних новоутворень (2008)

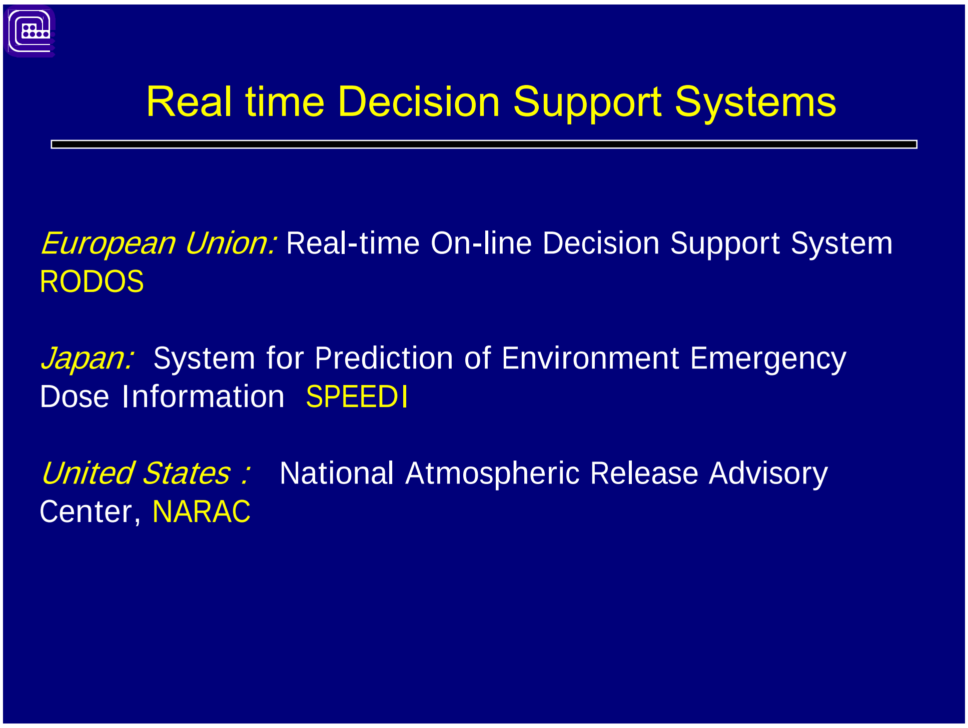
Mortality from cancer per 100 000 woman (2008)

第３次航空機モニタリング結果とセシウム１３７の土壌濃度マップの比較について
this map is taken from 文部科学省による放射線量等分布マップ
（放射性セシウムの土壌濃度マップ）の作成について





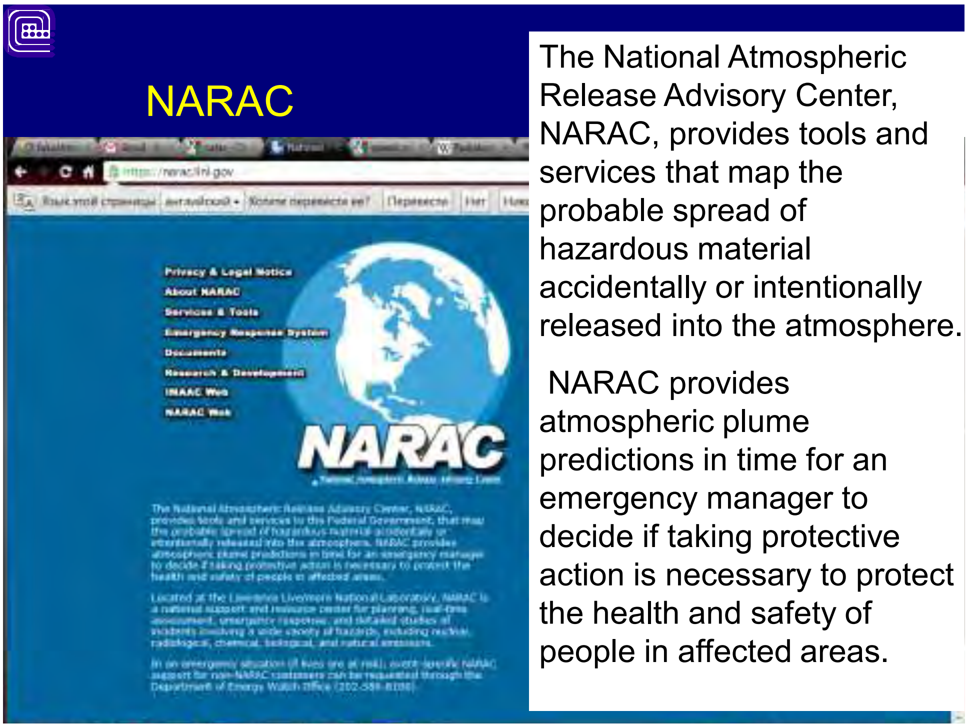
I will skip that part about the doses, because we are over the time, but I have only very short final part, so about situation in Fukushima and Ukraine in Chernobyl. Now, we see two maps in the same scale. We see that map of Chernobyl and map of Fukushima you know very well. You could compare the area contaminated in both countries' situation.



But, as I told you, our team who work in Chernobyl, and up to 1991, we haven't any contacts with abroad scientists. But in 1991 two things happened; we started cooperation in 1990 with the United States. At the same time, we started cooperation with the European Union, because in European Union, in United States and also in Japan, we started development, computerized system, receiving support for nuclear power plant accident, because you see the situation in Chernobyl. After the accident, people don't know to which direction should be evacuation, because it was impossible to have quickly data about monitoring. You should calculate propagation of radioactivity. How it's propagated?

What is the position? What should be done? Therefore, the European Union started in 1990 a project, main project is RODOS, Real-time On-line Decision Support System for Nuclear Emergency. The main idea is with combining one computer, different models; atmospheric dispersion, fallout, aquatic transport, food chain from the soil to grass, to grass to milk, to milk to human, to calculate doses, internal-external and to calculate countermeasures, efficiency. What to do to evacuate?

If you evacuate people, what dose will be advantage? Many, many different kinds of the countermeasures could be calculated.



At the same time in the United States, they provided the system, NARAC, National Atmospheric Release Advisory Center; and here in Japan, SPEEDI, also it's organization, Jared [ph] is representative of this organization, Jerry [ph] proper name.

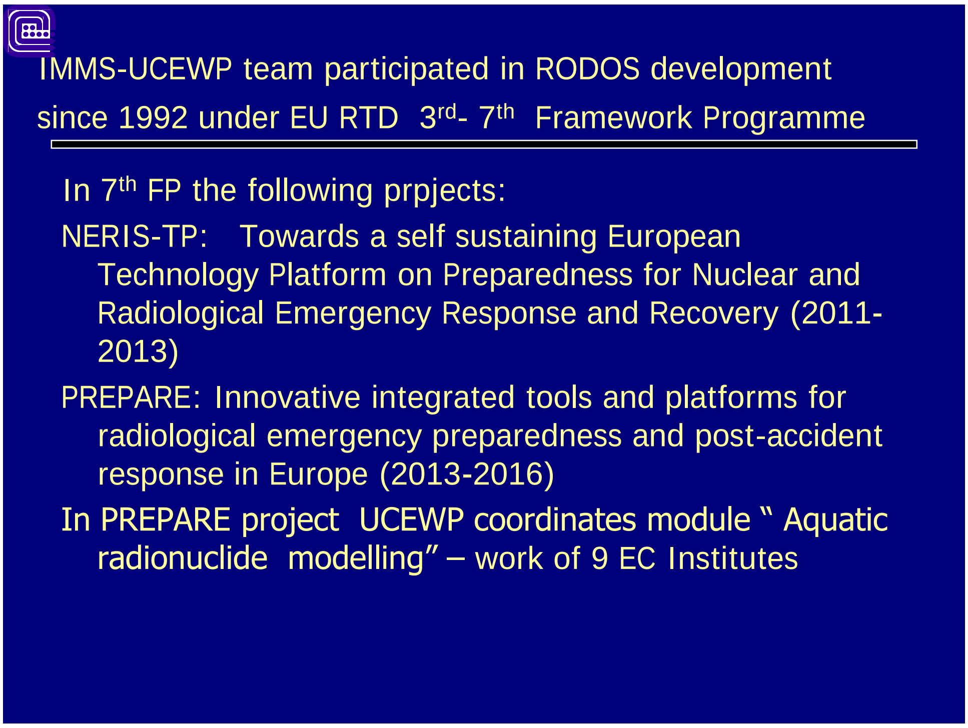
Moderator

Jerry.

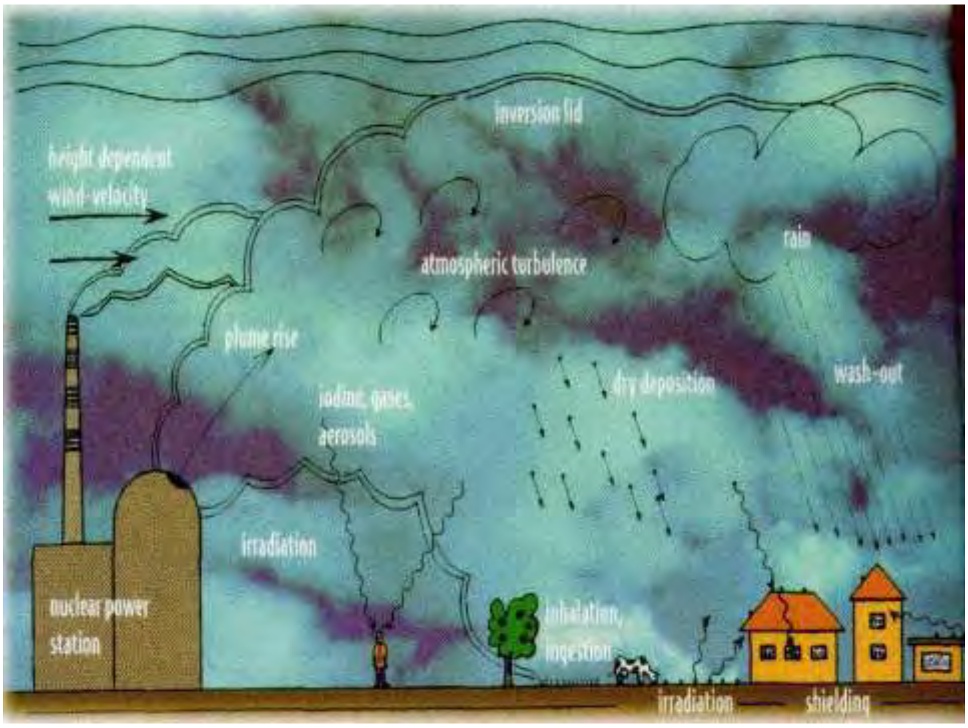
Mark Zheleznyak

Jerry, yeah. But what was the difference now, a few words about NARAC, you could find that NARAC [Unclear]. NARAC is concentrated mainly on atmospheric dispersion, [Unclear] atmospheric dispersion and doses for atmospheric dispersion.

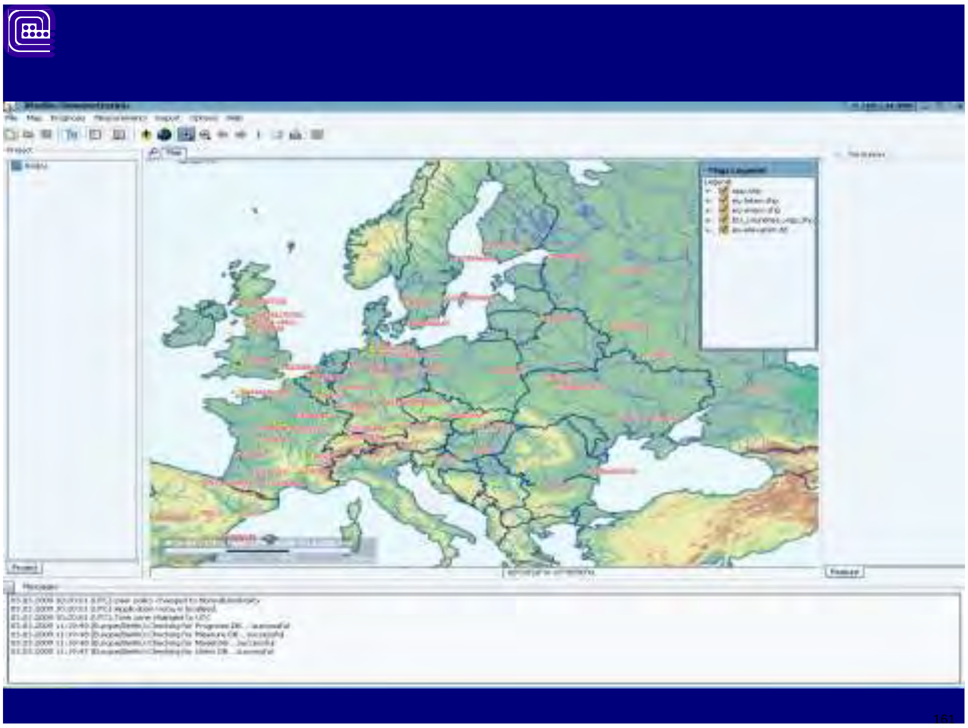
But Chernobyl demonstrated water is also important and, therefore, when European Union started this project, RODOS, main idea, analysis and prognosis, evaluation of strategies and countermeasures. It started development in 1992. It's my [Unclear] slide. It continued to do it.



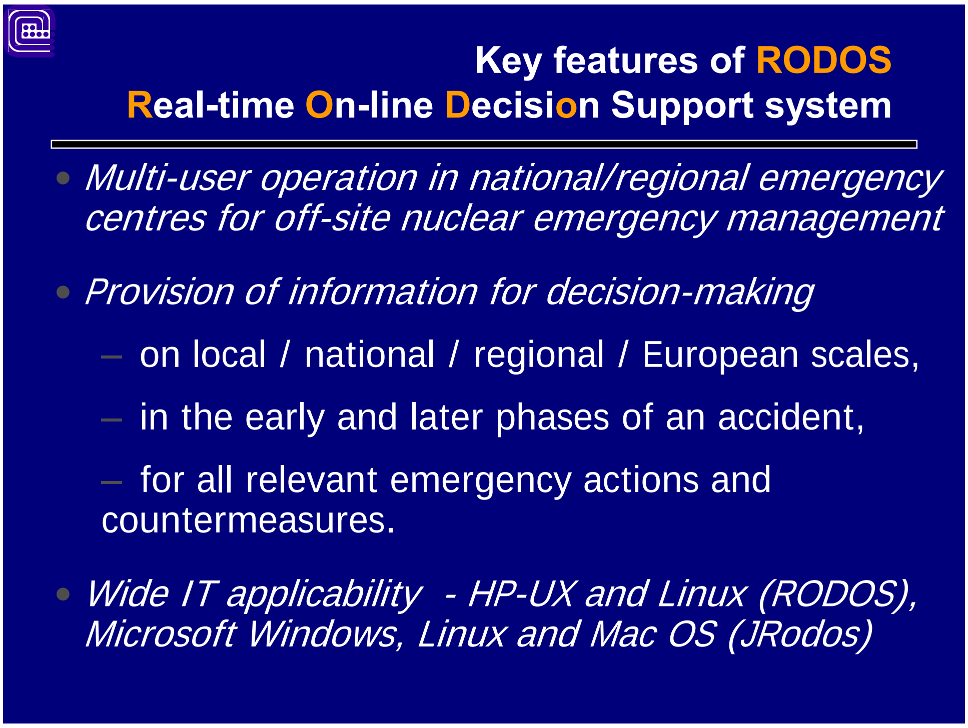
Now, our team participated in two projects of European Union. Ukraine is not a part of the European Union. But in some cases, we're eligible to participate. We participated and even I'm coordinator of aquatic modeling, coordinate activity of the nine European institutions in the four [Unclear].



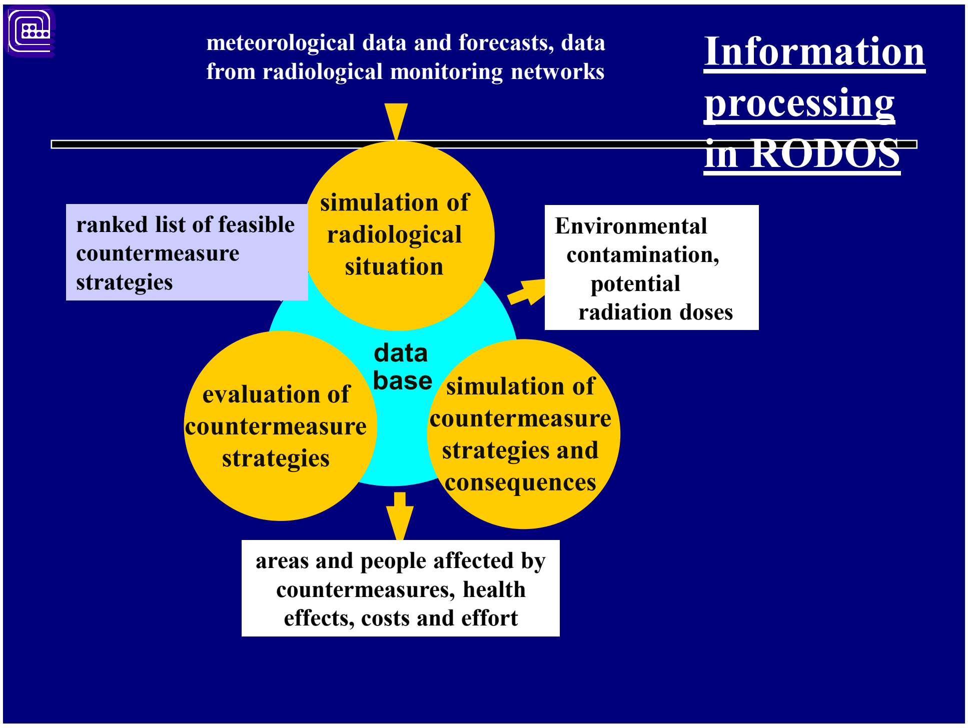
How the system is working? It's described all stages of the propagation of radioactivity after the accident.



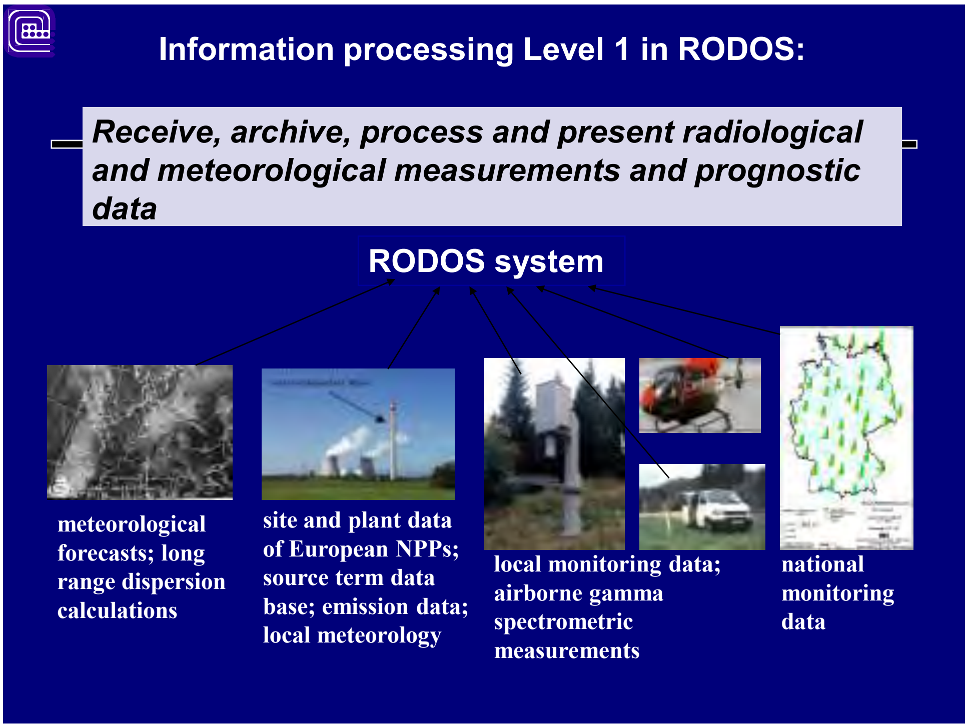
You see the interface covering all European countries.   You could zoom to any country.



We started in 90s, systems worked under the Linux for big Hewlett-Packard computers, but now we have new version of RODOS. It could be run even on the Notebook.

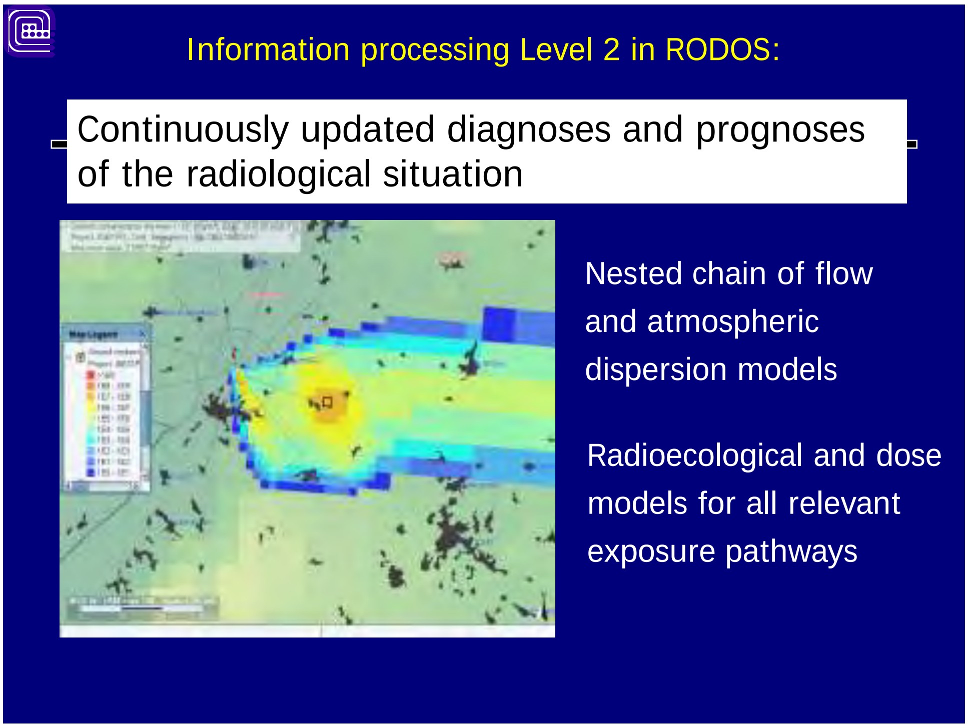


How it works? First of all, system should receive data of meteorological forecasting. We should have meteorological view in the territory to simulate directional propagation. If we include hydrological part, we should also have model of river transport or coastal area transport to calculate transport of radioactivity.



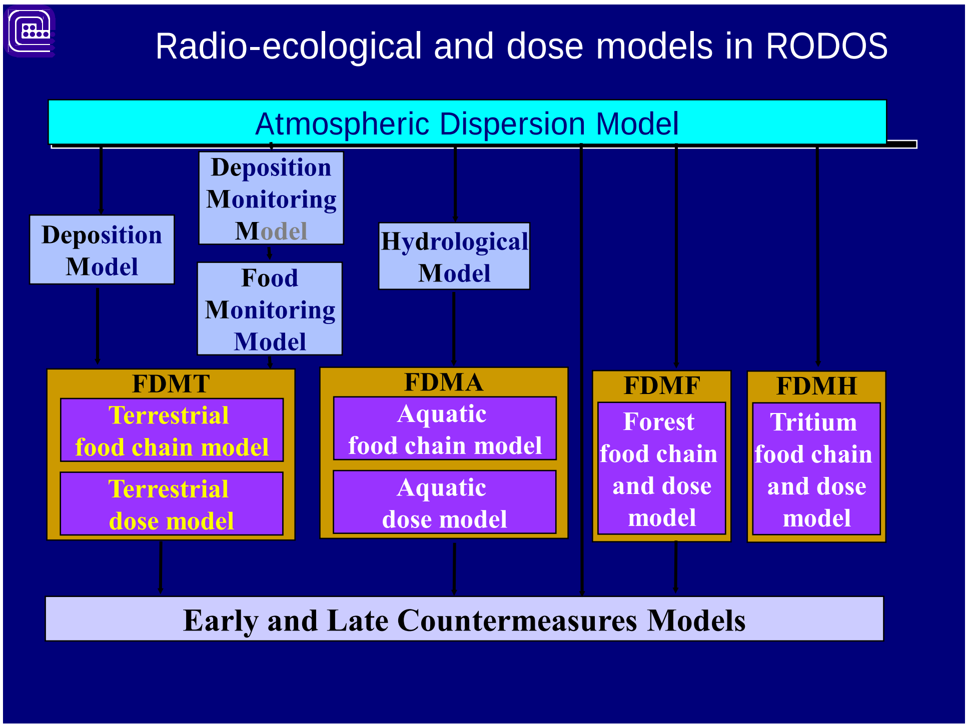
Also, it could use the data of different monitoring stations starting from meteorological forecasting for satellite pictures. Very important is data for meteorological systems of nuclear power plant and local and national monitoring system in the country to assimilate the data, because what we have problem, accident happened.

We started to simulate propagation of radioactivity, and we made forecasts, but when it's dispersion of radioactivity, you start to receive data from some measurement equipment, you have data. How to combine data with model in the real time to improve the modeling result, data simulation problem?



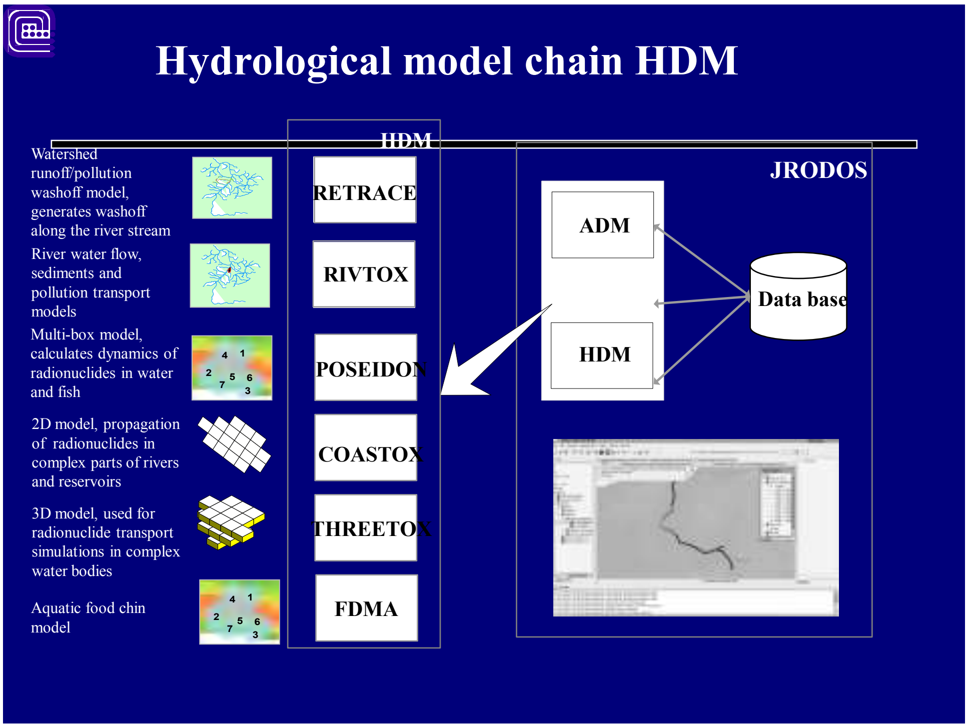
As a result, RODOS could simulate atmospheric dispersion.

The same also could simulate SPEEDI and NARAC.　What is now difference between RODOS and NARAC and SPEEDI?

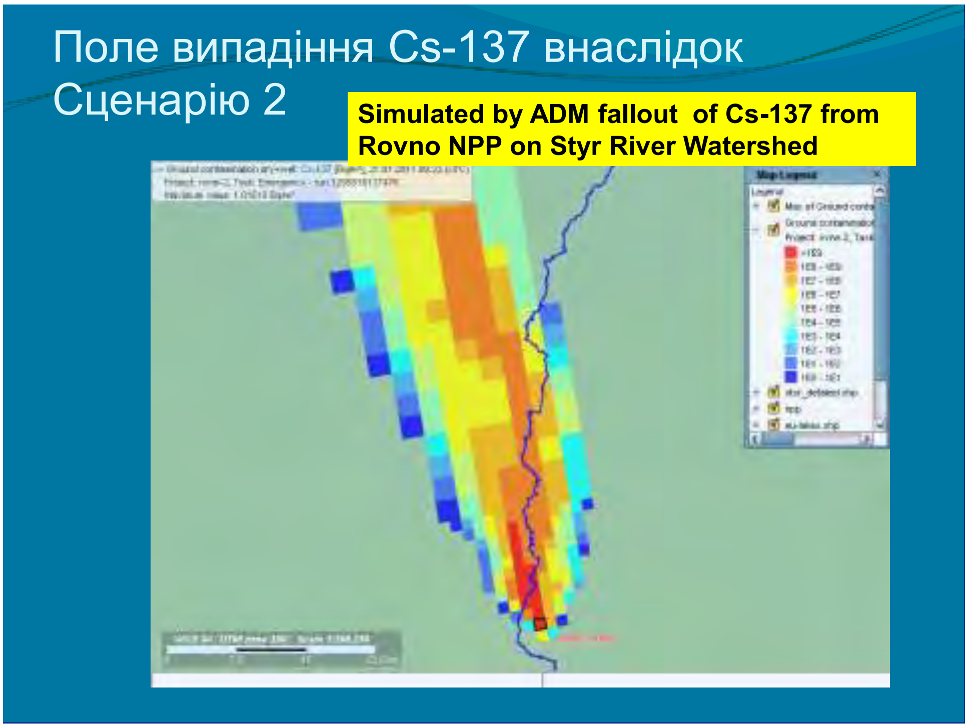


If you look at the structure of the models, we have, first of all, of course atmospheric dispersion model, deposition monitoring, but also we include now hydrological model. This hydrological model produced data for aquatic food chain to calculate doses. System could calculate doses from all pathways. If accident happened, you could calculate doses from external radiation from milk of the cow and from fish that was taken in this river. Also it includes forest, food chain model. The coordinator of this project is in Germany is institute, Forschungszentrum Karlsruhe.

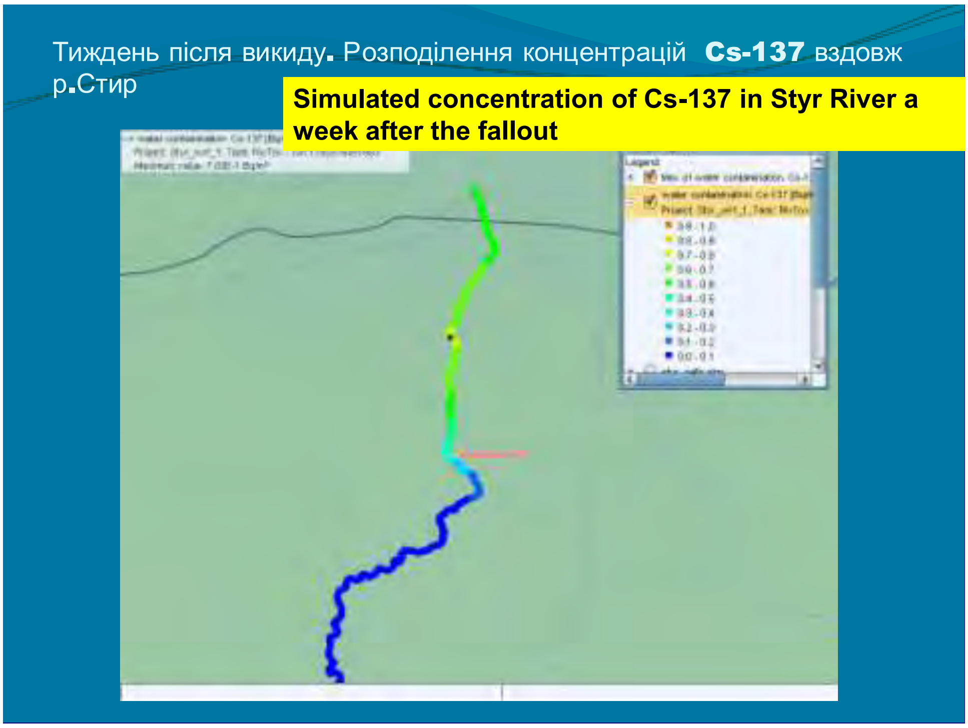
Now, its name is Karlsruhe Institute of Technology. For this period, maybe a set of European institutions are working in this project with different responsibility.



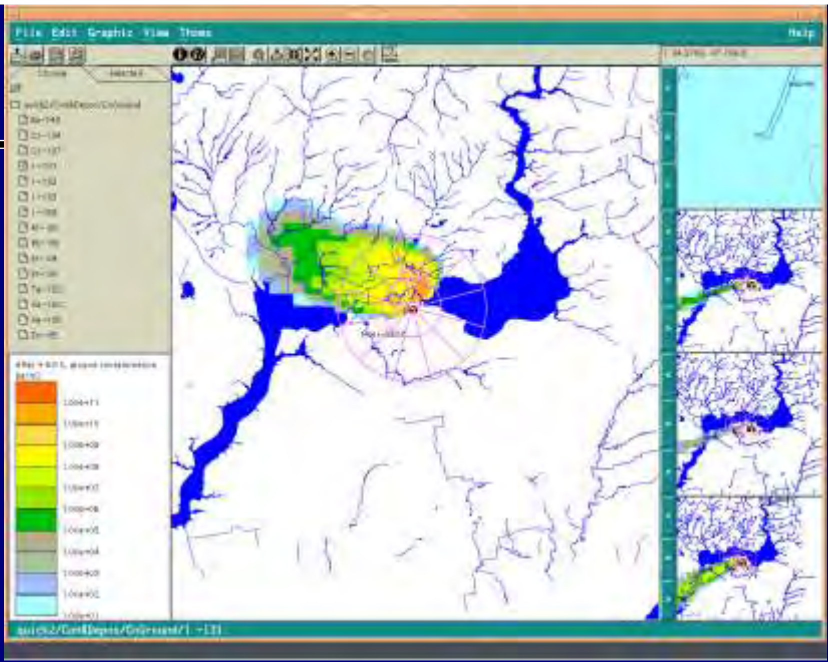
We have this hydrological model. We have watershed models, simple model, RETRACE. We have one-dimensional river model. We have model of fish contamination in the sea, POSEIDON. We have two-dimensional model similar to be applied to flood plain. We have our three-dimensional model that we applied to sea.We have dose model, FDMA, aquatic food chain.



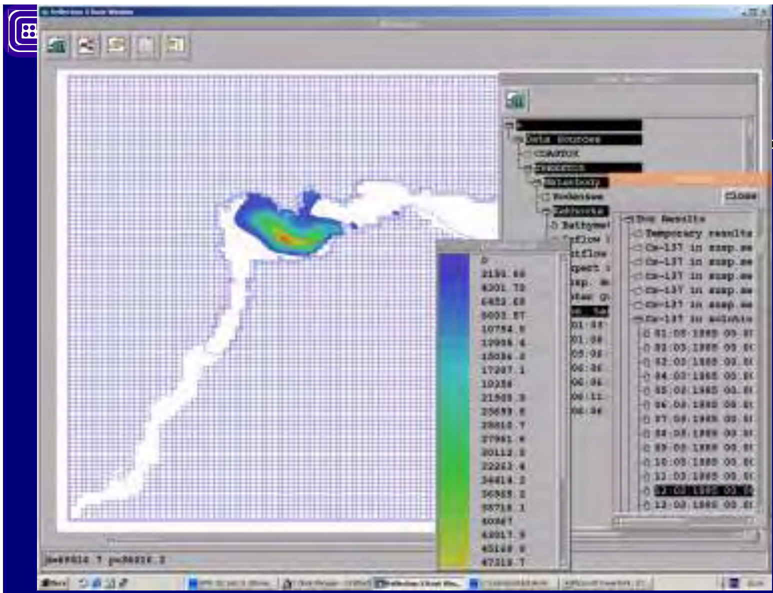
This is example and how it works. We receive data about the accident. It's example for Ukraine. We calculate fallout.



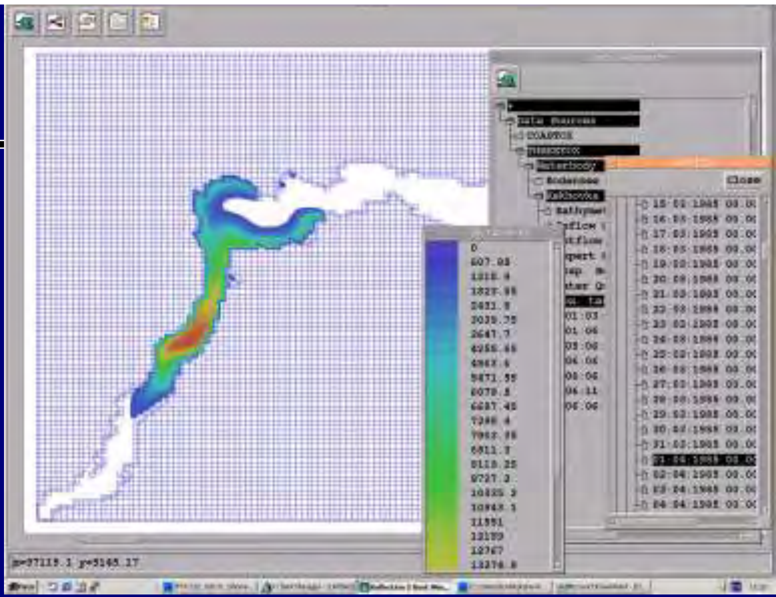
After that we calculate propagation in the river or if we have reservoir, it's also fallout and then we calculate how contamination propagated in this reservoir or in dike area and countermeasures, iodine tablets, evacuation, relocation, agricultural countermeasures, so RODOS calculates all these parameters.



Simulation of fallout Cs-137 from Zaporozhe NPP on Kakhovka Reservoir



Simulation of 137Cs dispersion in Kakhovka Reservoir by THREETOX model



Simulation of 137Cs dispersion in Kakhovka Reservoir by THREETOX model (32 days after fallout)

Information processing Level 3 in RODOS

Extent and duration of early and late countermeasures, and consequences of countermeasures

Simulation models for sheltering, evacuation, iodine tablets, relocation, decontamination, agricultural countermeasures

Health effects and economic models

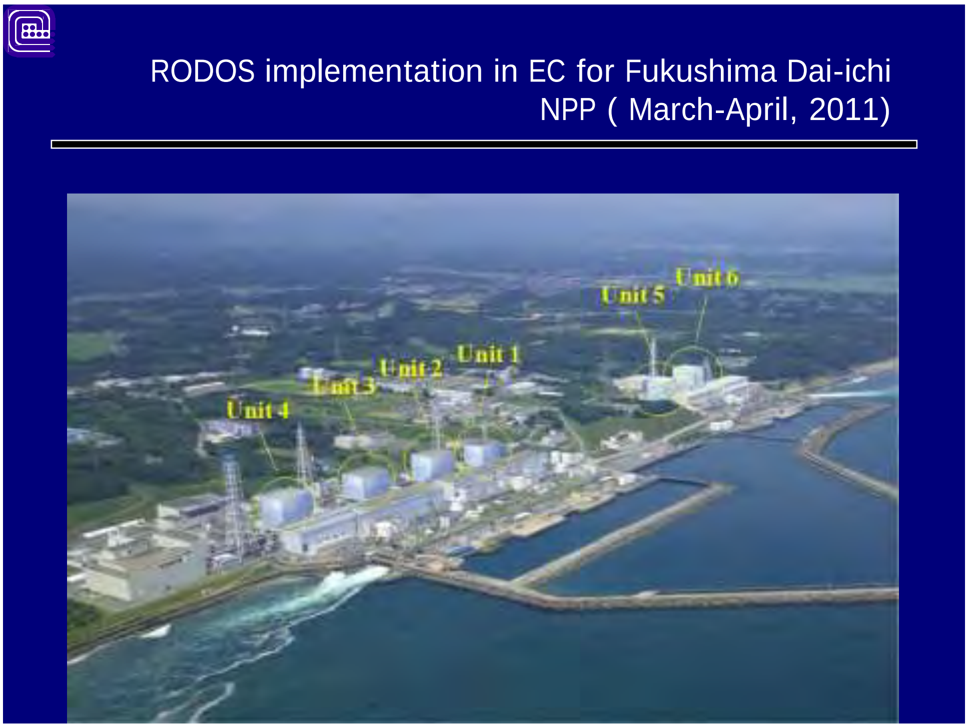
RODOS structure late phase

ADM
(near / far range)
Monitoring
Data assimilation

Potential areas for late countermeasures
- relocation
- decontamination
- food bans

Detailed model ERMIN
- relocation
- decontamination

Detailed model AgriCP
- food bans



Accident in Fukushima, when it happened? You know that my feeling from the [Unclear] site. The situation with information in Japan after the accident in Fukushima, my feeling is similar in Soviet Union in KGB time, because the information was very, very restricted. Of course, a lot of people who were inside the [Unclear], people who were in the European Union, for example in Tokyo, you have a lot of [Unclear] in the European embassies. Everybody worries what to do, to evacuate or not to evacuate? At this moment, people from Brussels, from European Commission say to Gordon Crawshaw [ph], my friend coordinator of RODOS development, a great guy.

They had given €10 million for all these 20 years for development of RODOS. Now, accident happened.

What have we done for atmospheric modelling of Fukushima releases?

- **Adaptation of RODOS to Japan (topography, land use from open sources)**
- **The Meteorological Institute of KIT and IMMSP/UCEWP have provided meteorological forecast data based on the American global model GFS (50 – 100 km) adapted with the model WRF for local application (10-20 km)**
- **The Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) has provided potential source terms for our calculations**

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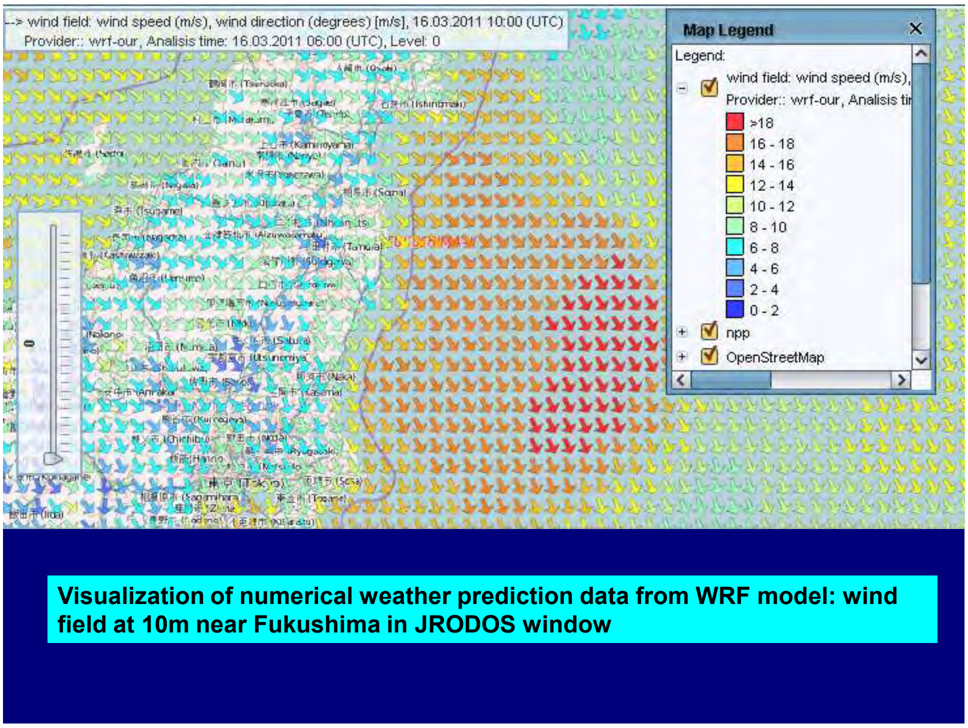
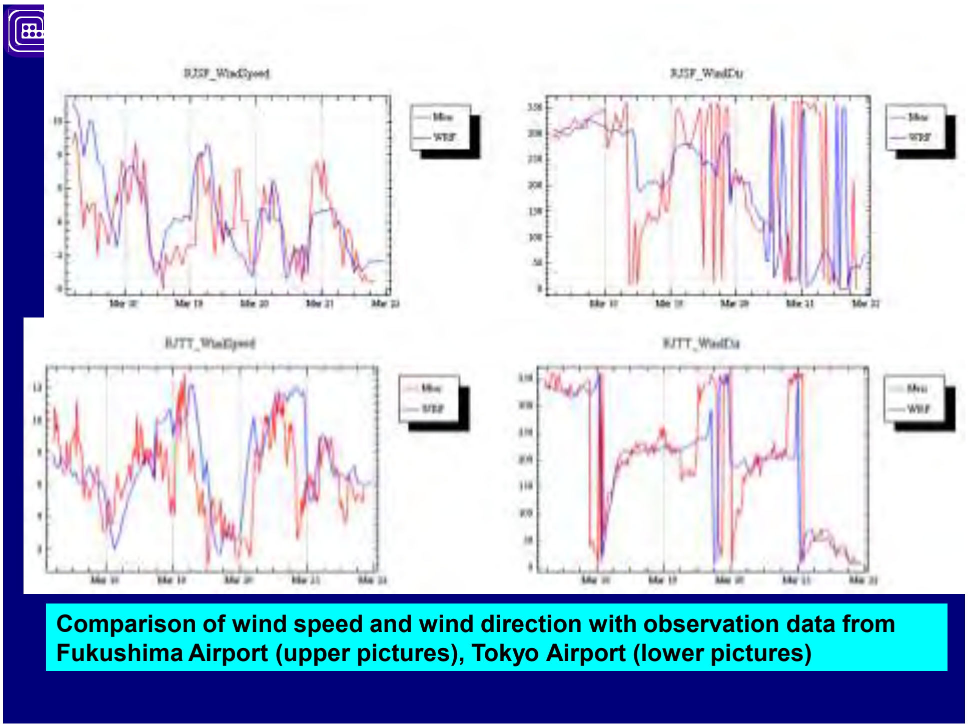
That calculated immediately consequences of the accident in [Unclear] and so we started with this [Unclear] and in March 2011, we started work or the estimate of – we should adopt RODOS for Japan, CCT&F in Karsruhe. What to use? We should use topography, land use from open source data. Of course most complicated, we should provide meteorological forecasts to Japan [Unclear] 10 to 20 kilometers. Many years we use American model WRF, W-R-F. We started some MM5 [ph] model.

Now, we use WRF. We apply this model researched by the [Unclear]. Several WRF meteorological centers produce forecasts for all group of research scale with 50 over 100 kilometers accessibility. But, of course, for simulation of propagation around [Unclear] is not enough [Unclear]. You should have agreed to 10 to 20 kilometers. Our task was to apply this WRF model to territory of Japan to receive meteorological forecasts 10 to 20 kilometers.



We did this in the first week after accident.　We see one of the examples of the wind field above the Japan territory.



Comparison of wind speed and wind direction with observation data from Fukushima Airport (upper pictures), Tokyo Airport (lower pictures)

Of course, we should validate the model.

We should demonstrate that we produce something reasonable in meteorology. We found open source data about the meteorology in airport, here in Fukushima Airport and Tokyo Airport. As we compare our results from wind direction, the theme looks reasonable.

Release scenarios

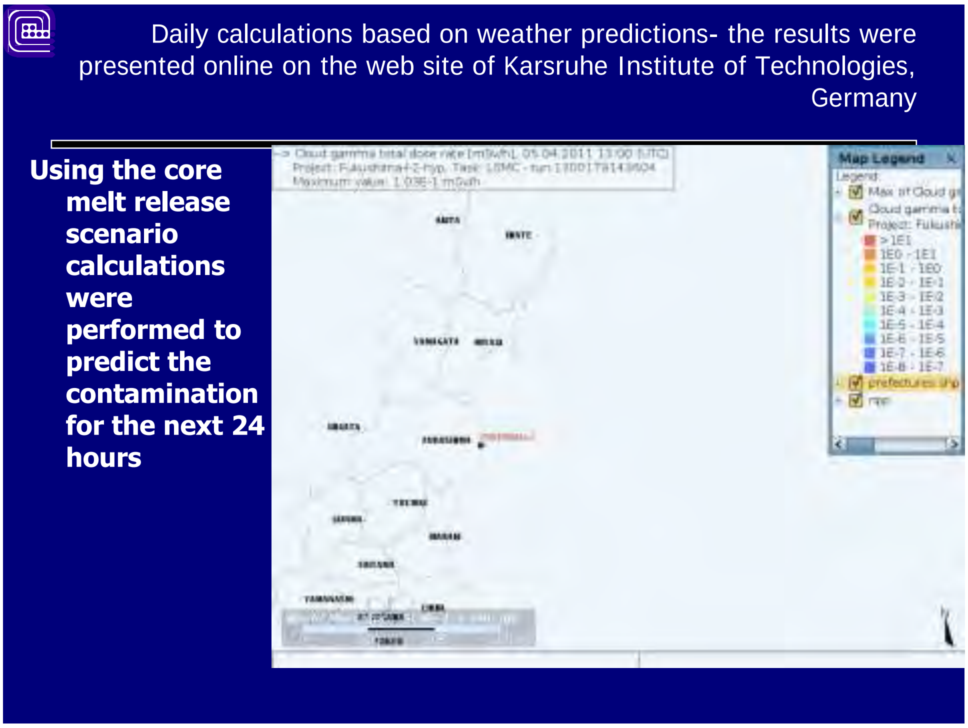
- GRS provided two source terms
  - Release from some fuel rods (lower estimation – gap release)
  - Release assuming a core melt (upper estimation – core melt)
- Estimated activit released (Bq)

	gap release	core melt	core melt max.
– Xe-133	4.E14	3.E18	3.E18
– I-131	4.E13	4.E16	4.E17
– Cs-137	2.E13	3.E15	3.E16
– Pu241	0.E00	9.E11	9.E12

- On 12.04.2011 the Nuclear and Industrial Safety Agency (NISA) estimated the release (in Bq) as follows
  - I-131 1.3E17
  - Cs-137 6.1E15
  - I-131 equivalent 3.7E17 (sum of I-131 + Cs-137)
- On 06.06 source term has been raised by factor of two

Most complicated is source term estimate.

At this moment, group of the Physics in Germany in the JRF [ph] company, they produce such kind of estimates and they give us these estimates.



(拡散状況の動画)

We have meteorology. We have estimate of the source. As a result, we could produce forecasts of propagation of atmospheric dispersion.
What we could not do? We could not provide simulation of the rivers, because all this information we found in the open sources. But we could not find information about river cross-section even if you have topography and river flow. We could not do this. But we could do a simulation of marine pollution. I cannot move this slide. We make comparison of the fallout.

It's reasonable. With the fallout, it was fun really. Also, we calculate scenario of the change of the direction of going to Tokyo and to simulate the worse situation for Tokyo. Starting from March 15 or 20, each day, this result was in the open access on internet. In European Commission and Europe, they could look for [Unclear] what will be direction of the wind, if [Unclear] what will be the propagation.

Structure of Information flow for HDM

JRODOS – ADM

↓

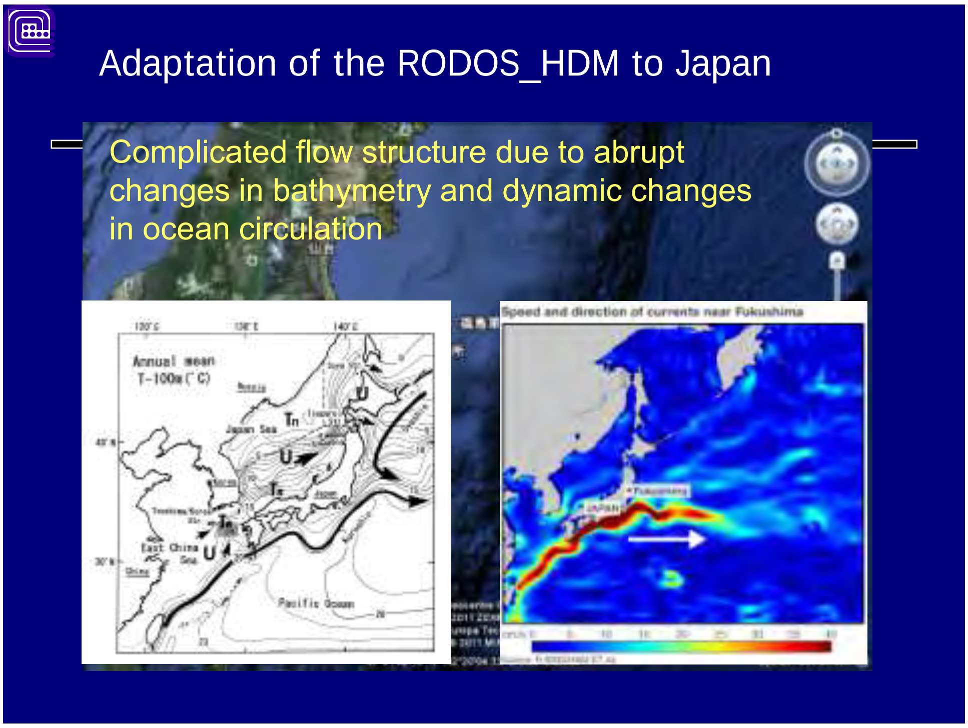
JRODOS – HDM

Hydrological Dispersion Module

3D Marine Hydrodynamics and Radionuclide Transport Model THREETOX

THREETOX:

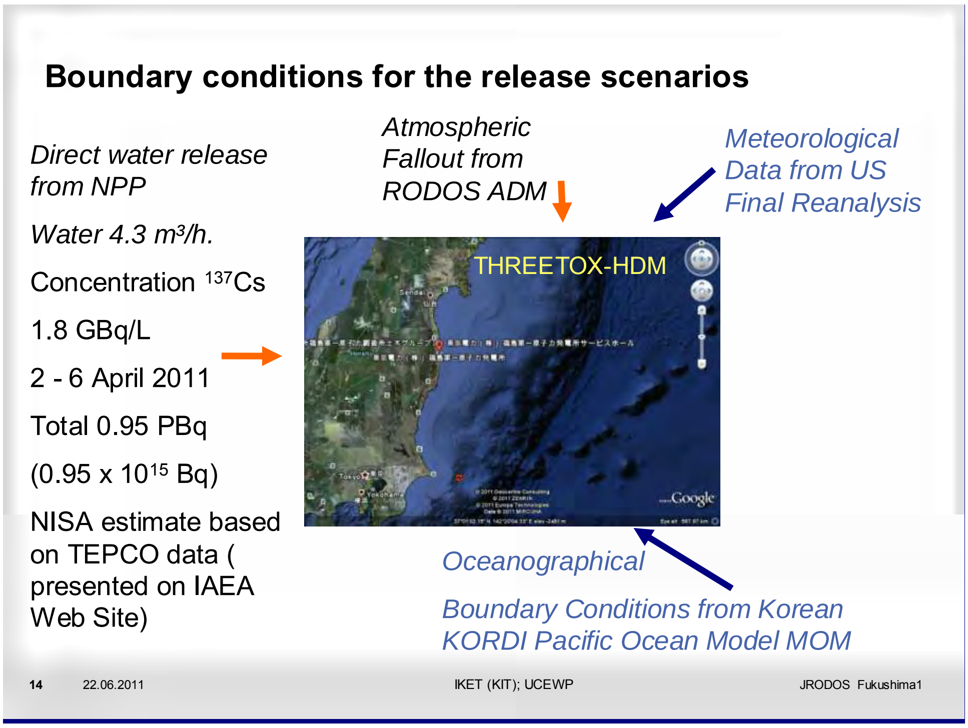
- Hydrodymics Module (temperature, salinity, currents)
- Sediment Transport Module
- Radionuclide transport in 3 phases (in solute, on suspended sediments, contamination of upper bottom sediment layer)



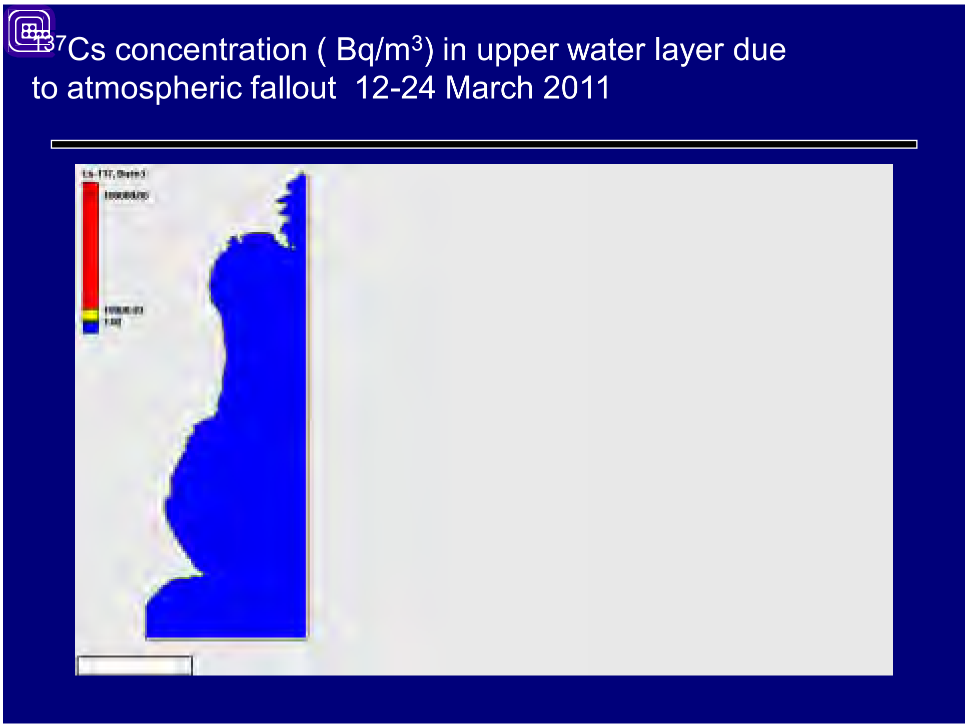
Now about marine modeling, marine modeling was a complicated task, because you know better, but now also I know a little bit about your situation. The situation near Fukushima is very complicated, because it's a point of meeting of two currents; KUROSHIO and OYASHIO. You see that KUROSHIO is going to the north. OYASHIO is going to the south. As you see now, it's not model; it's a reconstruction from the satellite about temperature above currents we see here, first of all, OYASHIO. Fukushima is near this point of this meeting. Therefore, in Japan at this point it's moving to north or to south.

Therefore, depending on the position of this point to limit the positive currents near coast of Fukushima, nuclear power plant, it could be direction to the north or to the south. But it's a difference between atmospheric forecast and marine forecast. At this moment, we have not a global marine forecast in the open network. But now it exists. Today, you could find global forecasting of currents for next day in the internet on the American website.

But at this moment, we use Korean model for this part of the Pacific.



How we use the model? We have [Unclear] of model. We take fallout from our RODOS atmospheric dispersion to the surface of the sea. We take boundary conditions here from KORDI Pacific Ocean Model MOM. We took this assessment also of the direct. We know that it was direct release to the sea, not to the atmospheric, but direct release to the sea. It also took assessment of this direct.

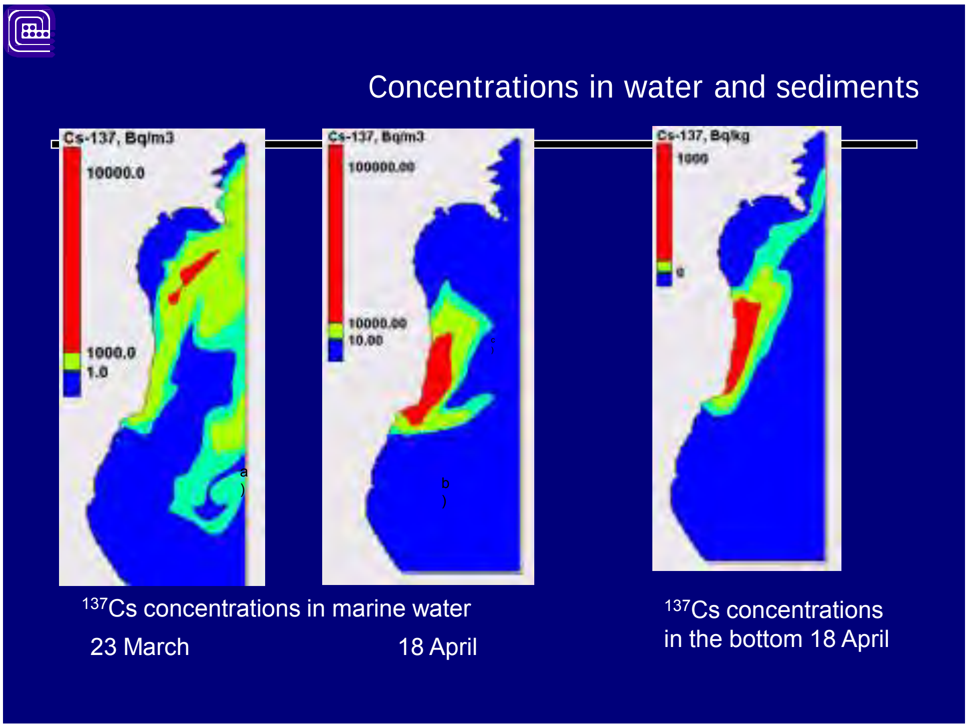


(拡散状況の動画)

Now, we see result of simulation of atmospheric fallout.　How it’s propagated in the sea?　Now, we see simulation of direct release.

^{137}Cs concentration (Bq/m^3) in upper water layer due to direct water release 2 - 6 April 2011

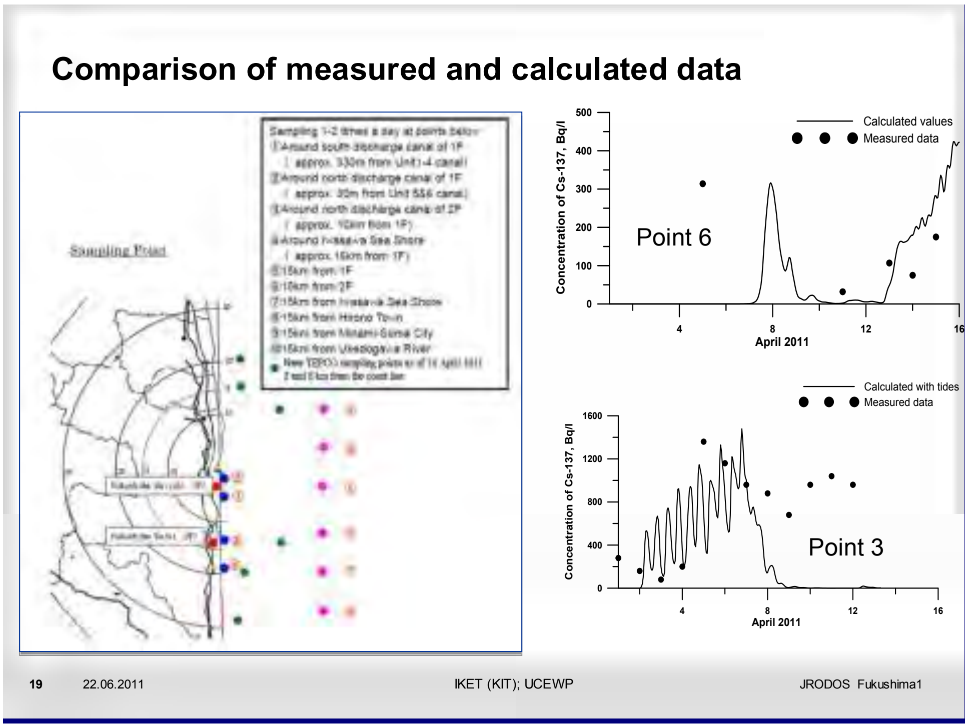
Simulations from 7-15 April



In static, you have only demonstration of concentration in marine water, two dates, 23 of March [ph] and 18 of April, and what's an important concentration of the bottom. Why this bottom concentration is very important? Because we also apply the model of the fish contamination.

Later I saw the data that if you say about fish contamination in the Japanese water, in principle, only biotic fish is contaminated. Biotic means fish who eats something from the bottom. Especially in this area where bottom was contaminated with cesium, so if you say about countermeasures, one of the countermeasures is prohibition of the catching fish in the areas where cesium is in the bottom, bottom is contaminated.

Also it's interesting to us, not only to us, to provide analysis of the most complicated situation in the coastal area where we have waste and this most contaminated area. As we know that several small rivers come here to the coast in this territory, they bring contamination from the watershed also to this area.



All this task is areas that are contaminated and we compare result of our simulation. This result that we found for measurement of concentration for some points, we've seen comparison of two points. In general, taking into account a big uncertainty in the source standard we have and here we finish simulation. The result looks reasonable.

But, of course, you could see what is the important lesson from this? Even in situation when we haven't enough data, when we have good prepared system for emergency response, you could receive a big positive response from this system, clinical assessment of the situation. It's very important because for population, the knowledge about the situation is very important. Therefore, when we say about potential cooperation with Japan in the field of radioactive pollution, it could be two directions. One direction is clear study of the contamination, secondary contamination of the watershed that you have in Fukushima, but other potential way. You will continue development of SPEEDI.

The system that could be applied for different nuclear power plants in Japan. I have a clear message to you from Gordon Crawshaw; it's a continuation of RODOS development. They're very interesting for [Unclear] connection maybe to use our experience and your experience to implement aquatic models to have comprehensive system for potential accident, because in any case, we hope that in my scientific [Unclear] is the last accident of nuclear power plant in the world. Who could guarantee? We see that many factors of many mistakes produced by engineers and people, scientists and many accidents possible and we should be ready, if you continue to use nuclear energy.

Even as we know Japan takes decision to shut down nuclear power plants but they were unable to do it. You should be prepared for the accident, because if you have a system that could predict consequences of accident, you could protect your population, diminish the damage after the accident. Therefore, it's interesting and important direction.

Conclusions on RODOS- Fukushima experience

The experience of RODOS quick implementation for Fukushima case study for EC by joint German- Ukrainian team – confirmation of needs for such systems preparedness for any country using NPPs

RODOS long-term countermeasures module – integrating experience of all basic EU institutes – can be used for SPEEDI extensions

Conclusions on Chernobyl aquatic studies experience

- The experience of model/monitoring based studies and support of water protection measures in Chernobyl area, first of all implementation of the different modeling tools for the specific tasks can be used in cooperation with Japanese researchers for watersheds of the river basins at Fukushima and studies of the coastal waters in the region
- Ukrainian researchers are enthusiastic about perspectives of joint researches with Japanese colleagues on the challenging tasks of Fuklushima water systems

We will be happy if our experience in Chernobyl will be applied here [Unclear].

We're enthusiastic for joint work together. Thank you.

＜質　疑＞

Moderator

Thank you very much.

Mark Zheleznyak

Sorry for lot of presentation but I would like to thank you.

[Japanese]

Male Participant

A political question I have for you. As you know all governments block information after or during accidents, assuming there's an accident in 5 years and you set up a beautiful working system, I mean you can predict the consequences, would you supply this information to the internet – distribute that information to the people who live in the affected area.

Mark Zheleznyak

Now in Europe, it's impossible to give all this information, because this RODOS system now is installed in all the European countries. Even if for example Slovakia, for example, is a country near border of Ukraine and even if they would like to close information about inside the country. Immediately neighboring countries; Hungary, Ukraine and Poland, they have the same RODOS system. Immediately, they will provide simulation for Slovakia and put it into the internet.

Now it's much, much difficult to call this improvisation. I might say I will demonstrate to you, also answer your question. One second, I will show you another blunt situation of the SPEEDI. I have such equations in Ukraine. If Japan has SPEEDI ready, why it was not really applied in this situation, because now we see scientific publications that demonstrated that SPEEDI produced good results for atmospheric fallout. One second, I will show you.

Of course, there are two questions. If you have good system and the system produced good results, you're engineer and you believed your results, but you have a boss. Your boss should present your result to the top level of government. It is a big point, because if it came out from [Unclear], in this situation boss could be afraid to present your result to the government, because the boss is afraid to make mistakes. It looks that such a situation happened in Japan with SPEEDI. I will show you.

Therefore, your question is right. You could have two components. Each country that used good decision support system also should have very clear procedure how to apply and to make information known us, publicity, but not only to the public, but also to the decision makers, top level, because in any case, that system has developed to be used by top level decision makers.

This is the information that we've found in press. Do you see it? Can I turn?
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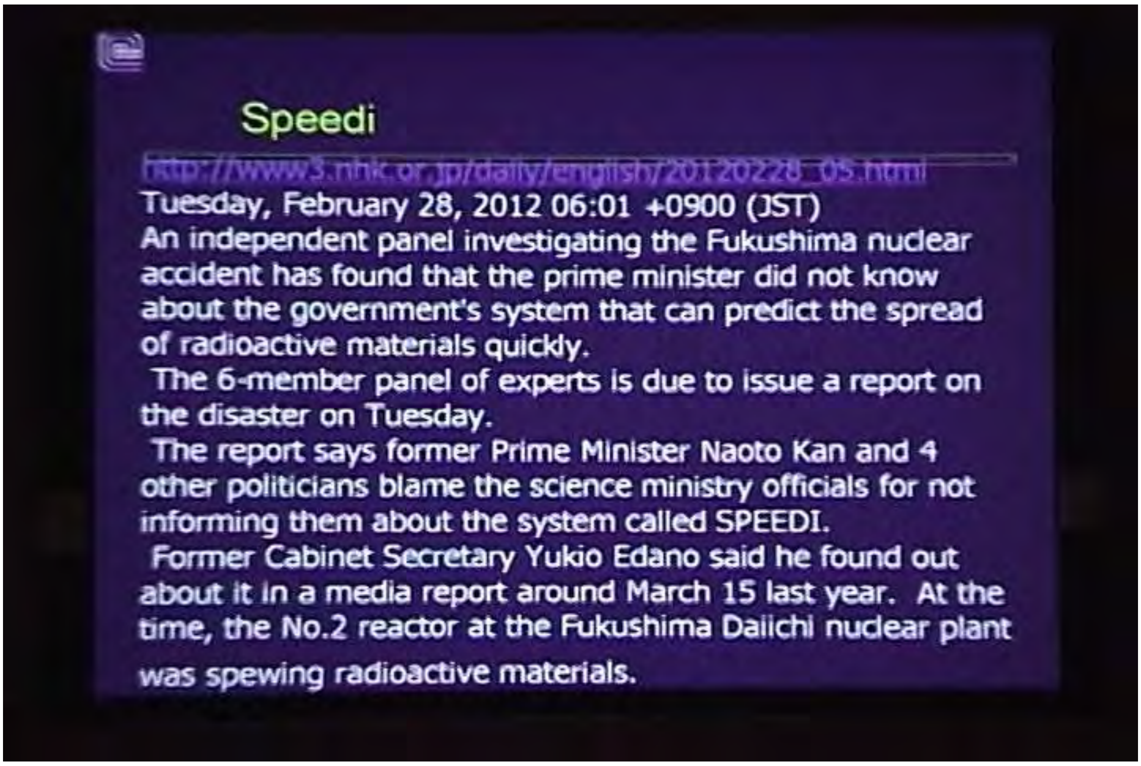

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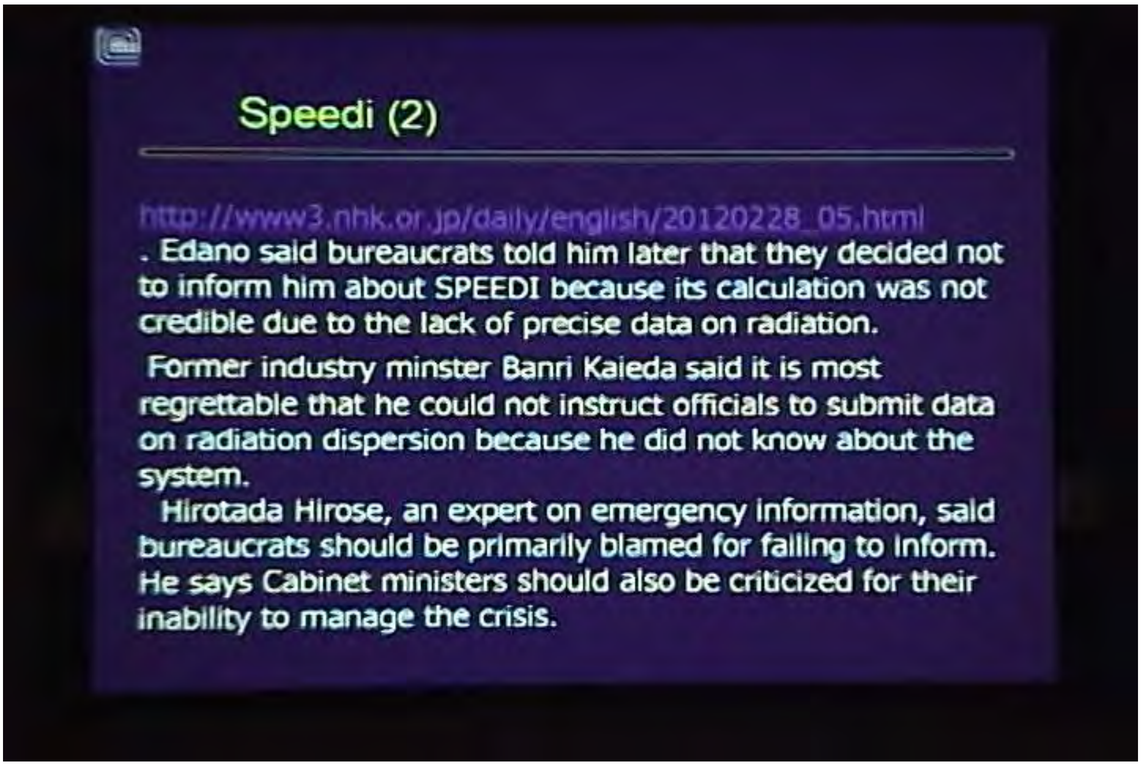

But I also want to show you that if we in Ukraine are applying not very exact meteorological model and here in Japan you use much better meteorological model and if we're applying – a rough estimate of the source term could produce much better result of the atmospheric fallout, SPEEDI for sure calculated more precise [Unclear], but this information didn't come through, not even to the public, but even not to the decision maker, to the government.

It demonstrated that it should be not probably [Unclear] but each country, how to use, in fact, the system that good scientific development could be immediately uptake by the government for the decision-making.

Male Participant
Okay. We can discuss it later on. Thank you.

[Japanese]

Male Participant

I have this question about the Kd, Kd to the sediment. You have shown typically about 100 days is required to reach equilibrium to achieve the Kd level. Is there any size dependency or time-definite?

Mark Zheleznyak
Yeah.

Male Participant
Generally, the finer is quicker or...?

Mark Zheleznyak
Yeah, we have two parameters, parameter Kd, it demonstrates level of Kd and parameter exchange rate coefficient is the speed of exchange. You're right. The sediment is high speed of exchange. If you have finer sediments, you will have a higher level of Kd and shorter time of [Unclear].

Male Participant
That is all included in the model?

Mark Zheleznyak
Yeah.

Male Participant
Okay.

Mark Zheleznyak
Because we apply the model now. In principle, this approach was started by Yasuo Onishi. He applied for the modeling, 3 years now for typical size of the sediment. He applied [Unclear] typical sizes. For each of the size, they own Kd. Also, we applied the exchange rate coefficient.

Male Participant
Thank you very much.

[Japanese]

Male Participant

Thank you very much for the comprehensive presentation. [Unclear]. My question is that possible difference between Chernobyl and Fukushima. You mentioned that you visited the Fukushima yesterday. Right?

Mark Zheleznyak

Yeah.

Male Participant

Yeah and I'm very interested in the dynamics of radionuclides in forests. In general, the amount of rainfall in Japan is larger than Chernobyl and also the rainfall is heavier like typhoon or rainy season and also forests in Japan are located on steep hills, so the river is maybe shorter and steeper than rivers in Chernobyl. Do you have any idea?

Mark Zheleznyak

I have a general idea, but of course to provide more detail, we should provide some ideas but first [Unclear] that, as I told you, it's some common that is territory mainly covered by forests both in Ukraine, as also in Fukushima. What is the most important lesson about cesium of the Chernobyl, what they say about this water exchangeable form that the amount rate has quickly diminished and, therefore, availability of the cesium for environmental transfer is quickly diminished. I'll show you that the same process will be here in Japan.

It means that it's important to you now to start to analyze this to provide measurements, not only total amount of cesium in your soil, but also separately amount of the exchangeable cesium and non-exchangeable cesium. As you will see diminishing of this amount of exchangeable cesium, you will see diminishing of the concentration of the river. I'm sure that the same process will be here. It's most important. But difference could be, first of all, these are slopes. You're absolutely right. You have much deeper slopes. It means that you will have much quicker erosion. It means also that the contaminated soil, upper layer of the soil will also be propagated in the river.

As a result, my feeling is preliminary feeling that process of self-modification

[ph] here will be quicker than we have in Chernobyl, because we have very flat territory, very small soil erosion, because practically no slopes and not also in the forest. Therefore, I might say that lesson from Chernobyl is optimistic and my feeling for Japan, because it's demonstrated that after 3, 4 years, the concentration of cesium in water drastically diminished. I'm sure that we'll be here, but of course it will not precede it. But I will not come to the data, but I would like to demonstrate to you also another optimistic information with the data of the volume maps.

You see map of contamination of Ukraine after the Chernobyl accident with cesium. You put attention that main contaminated area is in the northern part here. Also, we have map of the dose. But now after 25 years after the accident, we have map of the [Unclear]. You see that no correlation. This first picture gives the amount of cancer per 100,000 of men. In 2008, the second picture is amount of cancer of 1000 of women. This region is most clean in the country, one of the most clean. We see the highest level and here is the highest level of [Unclear] and difference is significant.

Here, for example, this area is very close to Chernobyl [Unclear], an average 250 cases per 100,000 and here near 350, significant difference. It's mortality from the cancer. This picture is from the same situation. It means I have calculation done and you have my calculation [Unclear], because amount of cancer through the doses, because it's very clear confusion between collective dose and amount of cases of cancer. If you compare these figures, you will see that it's very small in comparison with the real cancer. Without data, unfortunately it is. Population of Ukraine is 49 millions. This is calculation of the cancer for 70 years for the statistical data amount of cancer per 100 people.

If calculated from doses, amount of cancers, do it in Chernobyl. It is most affected population. People who work in Chernobyl area in '86, '87, many people, 126,000. I'm also a part of this set. I also worked in Chernobyl in '86, '87. From this amount, 60 million people died from cancer. I could guarantee that everybody from their family will be sure that this cancer result of Chernobyl. But if you provide dose calculation, you will see that only [Unclear] only 1600 died from real Chernobyl [Unclear] and, therefore, taking into account that this Chernobyl cancer is very small in comparison with the normal cancer.

You will see also that the reason for mortality in Ukraine from all sources. It's cardiovascular system diseases, heart attack and stroke, cancer, suicides, poisoning, transport accidents, murders, Chernobyl, risk calculated from the doses. This map [Unclear] it's proven that you could not find now Chernobyl impacted to cancer looking for the figures for their general mortality in the country. It means that the risk of Chernobyl was overestimated. I'll not say about the personal story of some person, I say about the big figures for whole country.

Male Participant
Okay.

[Japanese]

Moderator
Thank you very much for...

Mark Zheleznyak
Thank you for the questions.

[Japanese]

END