Radio-hydrogeochemical Monitoring of Area Adjacent to the "Shelter" Object

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INTRODUCTION

The accident at the Chernobyl NPP that happened in 1986 could be undoubtedly described as one of the greatest technogenous catastrophes of modern civilization. Into the epicenter of the accident there were involved large territories of Ukraine and Byelorus, which are now referred to as the Chernobyl exclusion zone. In its scale and diversity of the negative consequences, the Chernobyl accident turned out to be a national tragedy for the people of Ukraine, Byelorus and Russia. Its influence can be traced to this or that degree in many countries of Europe, Asia and all over the world.

The Chernobyl exclusion zone area within the Ukraine borders equals 2044.4 km^2. After evacuating people from the large territories, the excluded areas automatically extended approximately by 1800 km^2. As a whole, this area exceeds the territory of such a European state as Luxemburg by 1.5 times.[1]

As a result of the explosion, the active zone and the upper part of the reactor were completely destroyed. Barriers and safety systems for protecting the environment from radionuclides produced by irradiated fuel were also ruined. Therefore, immediately after the accident the most urgent problem was to build an available structure to protect the environment from further spreading of radionuclides out of the destroyed NPP 4th unit as well as working personnel from exposure to radiation. It took only six months to construct a structure which had no analogues in world practice. This structure was called the "Shelter" object (SO).

Having protected the area from direct radiation of the destroyed reactor, the SO did not provide complete reactor isolation from the environment and prevention of groundwater contamination by radionuclides. The reality of groundwater contamination is substantiated by the large amount of nuclear fuel in the ruined reactor (about 200 ton)[2] and radionuclide occurrence in internal SO water with activity of a few million Bq/l for strontium and tens of millions of Bq/l for cesium. At 2-3 km from the SO, down the groundwater gradient, the Prypiat river is located. Thus, the urgent problem after the Chernobyl NPP accident was to accomplish geological environmental monitoring around the SO, involving groundwater as the most mobile and the least protected component of the environment.

In the course of geological prospecting for Chernobyl NPP construction, appropriate geological-engineering and hydrogeological investigations were performed giving the principal estimate of soils and groundwater over the study area. However, the creation of the radiohydrogeochemical monitoring system was not intended to be the permanent control of the groundwater levels, chemical composition and radionuclide concentration over the area close to NPP power units. This omission was eliminated in the post-accidental period by spending large financial, human and technical resources.

DISCUSSION

In 1991, creation of the modern system of radiohydrogeochemical monitoring was started, involving the area around the SO.

According to the "Arial" program in 1991-1992, the first prospecting wells of 10m in depth were installed near the northern barrier of the SO site, and were drilled with continuous core sampling from the different soil layers. This provided for the pioneer geological-engineering examination of the SO site in the post-accidental state.[3] Determination of nuclear fuel and radionuclide distribution in deep soil layers down to the groundwater table was performed based on dosimetric and radionuclide core analysis. Experimentally, the amount of nuclear fuel within the operating site was evaluated (about 600 kg).

In 1993, an international contest was held concerning the conversion of the SO into an ecology- and radiation-safe system. As a result, Conversion Strategy was developed. One of its main items was the SO state examination and environmental monitoring.

In 1994, the net of observation wells was completed within the SO site which provided for the pioneer study of:

- Radionuclide contamination and groundwater levels dynamics;
- Recent geophysical and technogenous geolithological sections across the SO site and a more precise assessment of the fuel amount remaining after land surface deactivation.

There was also a determination concerning: distribution of airflow temperature, moisture and velocities; the principal water pathways inside the SO and major places of its accumulation; and the dynamics of radionuclides and nuclear fuel accumulation in SO water.

While analyzing the obtained data, it was revealed that the radionuclide concentration in the internal SO water abruptly increased (by 3 orders over 3 years).[4] This fact allowed us to consider the internal SO water as a new source of nuclear contamination for the geological environment. The possible hydraulic connection between the internal SO water and Quaternary aquifer initiated their parallel studying.

In 1995, it was determined that the main ways of water income to the SO premises was namely by. atmospheric precipitation, moisture condensation and technological solutions. Inside the SO, water moves along the principal water pathways. Depending on weather conditions, its discharge can vary in large ranges (up to 800 m^3/year). After interaction with concrete, water takes on alkaline carbonate composition and gains the capacity to dissolve cesium and uranium compounds. Water flow washes out the fuel-containing mass and removes the fuel particles and soluble radionuclides. Eventually, water is accumulated in the lower SO premises. In some cases, the water level inside the SO is much higher than the groundwater table in the adjacent SO area that can lead to water removal outside the SO, its inflow to groundwater, and then to the rivers.

The other source of groundwater contamination is the area around the SO containing, at the land surface, 0.5% of nuclear fuel ejected from reactor and other active zone elements .

Deactivation works performed in 1986-1987 considerably improved the radiation situation around the destroyed 4th unit of the Chernobyl NPP. Hence, by the moment of completion of the SO construction the radiation level at the site equaled 0.3-1.2 R/hour (compared to 40-1000 R/hour as of 1 August 1986). However, there was a large amount of fuel still remaining on the operating site covered by the artificial bank composed of gravel-sand mixture, concrete and asphalt coating. It was built as a special radiation-resistant layer to reduce the radiation level. The remaining fuel mass is a real danger for the environment because the artificial bank can't provide for safe isolation from physical-chemical influence of natural and technogenous factors.

The most dangerous factors for the geological environment are possibly water migration outside the SO and radiocontaminated area of the SO site.

In the course of hydrogeological studies the thickness of the Quaternary aquifer was determined to be 25-28m, the depth of the unsaturated zone is 3.5-7.4 m. The unsaturated zone is composed of both technogenous soils (formed during the Chernobyl NPP construction and accident consequences liquidation) and Quaternary deposits.

The Quaternary deposits within the unsaturated zone are represented by fine- and medium-grained sands with sandy loam and loam interbeds. The conductivity of water-bearing sands is 15-20 m/day (medium-grained); 2-4m/day (fine-grained); 1-2m/day (powdered); -0.1m/day (loam) and 0.5m/day (sandy loam).

The magnitude of the groundwater table fluctuations in 1996-1997 equaled 0.4-0.6 m. The groundwater flow gradient was 0.001 m/m. In the summer period, groundwater temperature varied from 10.4°C to 14.2°C.

Mineralization of groundwater sampled from wells located close to the SO site and down the groundwater gradient from the SO was 503-962mg/l. This parameter for wells located up the groundwater gradient from the SO was 174-256mg/l.

According to the anion composition, groundwater is hydrocarbonate, hydrocarbonate-sulfate*, and sometimes sulfate-hydrocarbonate. By cation composition it is sodium-calcium, rarely sodium and calcium-sodium; pH varies from 4.2 to 9.8.

As a result of different chemical substances, penetration into the destroyed reactor (for stopping the fire, decreasing the probability of chain reaction, deactivation, dust suppression, etc.), some of them with time migrate into groundwater changing its natural composition by increase of sulfate, chloride, phosphate and nitrate concentrations.

In the course of monitoring improvement, radioisotopes (T-tritium, ^{90}Sr, ^{137}Cs, ^{238}Pu, $^{239+240}$Pu, ^{241}Am) in groundwater were also studied.

Concentration of radioisotopes in groundwater is as follows: ^{137}Cs -444Bq/l, ^{90}Sr -229Bq/l (excluding well 3-g with all-time high concentration of ^{90}Sr up to 3820Bq/l); ^{238}Pu -3Bq/l; $^{239+240}$Pu -5.6Bq/l; ^{241}Am -8.5Bq/l.

Water concentration of ^{90}Sr and ^{137}Cs in the SO lower premises reaches 4,400,000Bq/l and 98,000,000Bq/l, respectively.

Tritium was chosen as an indicator for migration of the internal SO water to the Quaternary aquifer. The groundwater sampled from wells located along the same flow streamline down the groundwater flow from the SO are of higher concentration of tritium (to 4,037Bq/l) as compared to its concentration in the other area (10-20Bq/l). Probably, it indicates the migration of the internal SO water into the geological environment, because the tritium concentration in the internal SO water achieves 20,000Bq/l. At the same time the groundwater flow rate near the SO is rather low (up to 50m/year). The time when the contamination front reached the Prypiat River was evaluated at 150-200 years. This evaluation is conservative, because it does not take into account the broadening of the first part of the contamination front and sorption properties of soils. To provide precise information of contact between the internal SO water and groundwater, long-term observations are required.

The soils within the SO site were studied with radiochemical and radiometric methods by analyzing core samples and wells gamma-logging. Uranium, plutonium and products of nuclear fuel fission were identified by laboratory analysis of core samples.

The highest concentration of uranium (5.11E-2**%) was detected in the northeastern part of the SO site at the depth of 2.6-2.9 m (pre-accidental land surface). In the deeper soil samples, the uranium concentration does not exceed 8E-4%. Within the zone of natural soils it equals nE-5%, where "n" ranges from 1 to 10.

In sampled soils, plutonium concentration correlates with that of uranium. Its maximum value is close to that of uranium and equals 1.6E+4 Bq/g. In the deeper soil samples, the plutonium concentration does not exceed 1-13.4 Bq/g, within natural soils zone it is 0.01 Bq/g and less.

At present short-living fission products (^{144}Ce, ^{106}Ru, ^{125}Sb, ^{154}Eu, ^{60}Co) are identified only in the sampled soils with high uranium concentration by gamma-spectrum at long exposition of measuring.

^{137}Cs and ^{90}Sr were found in all geological zones in different concentrations. Maximum concentration of ^{137}Cs was observed in well 4g (2.5E+4Bq/g) and 9-1A (8,7E+4Bq/g) at the depth of pre-accidental land surface. Minimum ^{137}Cs concentrations (0 3-0.6Bq/g) were observed in the natural soils zone.

^{90}Sr concentration in post-accidental technogenous deposits varies from 0.2 to 2.5E+4Bq/g. Maximum concentrations are associated with pre-accidental land surface. In the upper part of the Quaternary aquifer ^{90}Sr concentrations are 0.0 -0.2Bq/g.

Therefore, in the vertical cross-section of the study area, the most radiocontaminated are soils near pre-accidental land surface. The less contaminated are post-accidental technogenous deposits. Water migration of radionuclides or their mechanical removal caused contamination of pre-accidental soils (both technogenous and natural).

CONCLUSION

To the Chernobyl accident lessons, we can ascribe the necessity of preventive monitoring accomplishment in NPP areas to control the soils and groundwater state during regular NPP work and to evaluate the sources, scales and dynamics of radiocontamination of the geological environment in the case of extraordinary situation.

The principal monitoring wells should be disposed in the direction of the lateral groundwater flow.

It was revealed that the groundwater radionuclide concentration is non-uniform along the aquifer thickness, being maximum in the upper part of the aquifer. Therefore, the long well filters providing for only averaged sampling of the whole aquifer thickness are not suitable. Short filters installed in the upper part of aquifer are preferable to long ones.

In the case of a multi-aquifer system a group of wells should be equipped for studying interaction of these aquifers both in ordinary and extraordinary situations.

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* by hydrocarbonate-sulfate water is meant the prevalent concentration of sulfate ions in groundwater composition

** by 5.11E-2 is meant 5.11x10-2

Session G, Track 1: Public Health Issues III

Friday, September 11, 1998
10:10 a.m. - 12:00 p.m.

Chair: Gary Goldberg, United States Department of Energy

Public Health Issues: Considerations for Post-Emergency Response Panel Discussion

Presented by the Radiation Emergency Assistance Center/Training Site (REAC/TS)

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INTRODUCTION

In 1895, Professor Conrad Reontgen published a report on the discovery of x-ray (Roentgen, W.C., 1898). Shortly thereafter, the first x-ray induced health effect was reported in scientific literature (Edison, T., et al, 1896). Over the next 45 years, radiation accidents were often unreported and associated medical data were archived in personal files of treating physicians. In the early 1940s, the development of nuclear weapons and their subsequent use in Hiroshima and Nagasaki resulted in the establishment of a medical/epidemiological database for follow-up on the Japanese atomic bomb survivors. With the advent of peacetime applications of nuclear energy for electrical power generation, as well as applications in industry, agriculture, medicine and consumer products, more and more radiation accidents were reported. Many of these accidents were studied and medical information archived in the accident registries as part of the programs of the Radiation Emergency Assistance Center/Training Site (REAC/TS). (Lushbaugh, C.C., Fry, S.A., Ricks, R.C., 1980). The majority of the reported serious worldwide radiation accidents involved not more than 10 persons.

DISCUSSION

Prior to 1979, multi-casualty incidents involving radiation were limited to events in the Marshall Islands (1954); Palomares, Spain (1966); and Thule, Greenland (1968). In March, 1979, the accident at Three Mile Island Nuclear Power Plant, although not a radiological disaster, caused considerable re-evaluation for post-emergency response capabilities to radiation accidents in the United States. It was quickly realized that the potential impact of multi-casualties on overall health care systems and population follow-up could be significant. More and more attention was therefore given to pre-planning, medical capabilities, and training for radiation accidents. Subsequent accidents in Chernobyl (1986) and Goiania, Brazil (1987) reinforced the need for continued planning and preparation for major multi-casualty radiation accidents.

While accidents are by definition, unplanned, there exists today another potential for multi-casualties associated with ionizing radiation. We live in a community at risk from terrorist acts involving weapons for mass destruction, including chemical, biological, and nuclear devices. Nuclear terrorism may involve crude or sophisticated nuclear weapons, radiation dispersal devices, sabotage of commercial nuclear power plants, or simple radiological devices such as stolen sources. As part of the Nunn-Lugar Weapons of Mass Destruction legislation, training of fire, police, technical, EMS and medical personnel for post-emergency response is being conducted throughout the United States. Two hundred cities are currently on the list of training sites.

Over the past 22 years, the REAC/TS program has trained 4,373 physician, nurses, EMTs, health physicists, and others in medical management for radiation accidents through courses sponsored by the United States Department of Energy. Specific courses are offered for the emergency department personnel, health physics support personnel, and physicians/nurses involved in post-emergency care. Historically, course participants have come from areas of the country where the use of nuclear energy for electrical power production, R&D employing ionizing radiation, or military applications are concentrated.

An incident resulting in a number of persons having exposure to penetrating radiation sufficient to result in the acute radiation syndrome (and possibly to serious localized injuries) will have significant impact on the medical community and health care organizations, even after the early problems of victim extrication, triage, trauma management, medical and radiological assessment, decontamination, and supportive treatment are taken care of. Those with the acute radiation syndrome may require transfer to facilities for long periods of costly hospitalization by highly skilled staff, while those with less severe exposures will require frequent assessments and careful follow-up by local practitioners and admission to hospitals when infections, bleeding, skin injuries or other problems are manifest. Planning for emergency response and emergency care have been published by Leonard & Ricks (1980) and Berger & Ricks (1992).

Decisions regarding administration of antiviral and antibacterial prophylactic agents, appropriate growth factor therapy, the use of peripheral or cord blood stem cell transfusions, and assessment and interpretation of dose information will require consultation with experts in radiation medicine, hematology, immunology, radiobiology, and transplant therapy, while management of localized injuries will require experts in radiation medicine, dermatology, vascular and reconstructive surgery. If radioiodines are released in an incident, medical personnel will be needed to assess thyroid function of involved persons.

In addition, during and after an incident, health care practitioners will be inundated with requests for medical evaluation and treatment for conditions which may be psychosomatic in origin.

CONCLUSION

This panel discussion will address ways the medical community will be impacted by a serious radiological emergency, beginning with hospitalizations for the seriously ill, home/community care for others, and the usual medical problems associated with evacuation of the population. In addition, considerations for bioassays, whole-body counting, internal dose assessment, and requirements for epidemiological information will be discussed.

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