Post-Chernobyl scientific perspectives:

Reports on topics addressed at technical sessions of the International Conference convened in Vienna 10 years after the Chernobyl accident

ENVIRONMENTAL CONSEQUENCES

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A question often posed by the public and decision-makers is: "What is the expert view of the environmental damage that resulted from the Chernobyl accident, and what can be expected in the future?"

Deriving a single answer is difficult: there were large variations in the levels of environmental contamination, a lack of a common unit of measure with which to present the varied environmental consequences, and a broad range of possible interpretations of the consequences. Traditionally in radiation protection, the natural environment is considered to be protected if the human population is protected. So in most cases, the consequences are viewed solely in terms of impact on humans. It is for this reason that the most effective methods of restricting the natural course of the transfer of radionuclides in the environment (by so-called countermeasures) have been aggressively studied during the last 10 years. Besides providing important information for the development of radiation protection policy for the areas affected by the accident, advances have been made in basic radio-ecological research.

Presented here is a brief summary of recent estimates of the initial releases to the environment as a result of the Chernobyl accident, the observed impacts from increased levels of radiation on plants and animals near the site, and the transport of radionuclides in the environment.

Recent estimates of radioactive releases. Broad agreement has been reached among various estimates concerning the initial environmental release due to the accident. Most of the material released was short half-lived radionuclides. Releases to the environment of some radiologically important radionuclides (iodine-131, caesium-134, and caesium-137) are estimated now at a factor of two to three higher than in 1986, namely 2 exa-becquerel (EBq), 50 peta-becquerel (PBq) and 90 PBq, respectively. However, the reassessment of the source term has had no impact on the assessment of individual doses, which were based on the environmental or whole body measurements made in the affected areas. The total amount of radioactive material still present in the environment after 10 years has decayed to about 80 PBq of long-lived radionuclides, principally caesium-137 and strontium-90, or about 1% of the total amount released. *(See table, next page.)*

Overall patterns of contamination by these long-lived radionuclides have remained essentially unchanged over the last 10 years, with relatively little secondary transport of material. Hot fuel particles released from the reactor are one of the factors of this accident that differentiate it from weapons fallout material. Close to the reactor, these particles are beginning to disintegrate and further study is needed to understand their final distribution in the environment.

Direct effects on plants and animals. The highest doses immediately after the accident were received by plants and animals within a radius of 30 kilometers from the reactor. Contamination levels typically reached several tens of mega-becquerel (MBq) per m^2 (thousands of Ci/km^2) in some localities and external doses would correspondingly have been of the order of several tens of gray (Gy) to vegetation and small animals in the first month from the short-lived radionuclides. By the autumn of 1986, the dose rate at the soil surface dropped by a factor of 100 of the initial value.

Social, health, & environmental effects

Residual radioactive material in the global environment as a result of the Chernobyl accident in April 1986

Significant radionuclide	Released in 1986 (PBq*)	Remaining in 1996 (PBq)	Remaining in 2056 (PBq)
I-131	200–1700	0	0
Sr-90	8	6	1 5
Cs-134	44–48	1 6	0
Cs-137	74–85	68	17
Pu-238	0 03	0 03	0 02
Pu-239	0 03	0 03	0 03
Pu-240	0 044	0 044	0 03
Pu-241	5 9	3 6	0 2
Am-241**	0 005	0 08	0 2

*1PBq = 10^{15} Bq Estimate of release decay corrected to 26 April 1986, the day of the accident **The activity of americium-241 in 1996 has increased since 1986 as it is a daughter product of plutonium-241 (half-life 14 years) This increase has to be considered in any radiological prognosis, however, the doses from americium-241 will not exceed the present doses from other radionuclides

Above. **A chestnut tree in bloom inside the 30-km exclusion zone. *Right:* Where forests were cut down after the accident, new trees are regenerating near the Chernobyl plant, which is on the horizon** *(Credit Eric Voice)*

Direct radiation injury to plants and animals was reported only in local areas within the 30-km exclusion zone. Different organisms in the natural environment were exposed to high doses, and the lethal doses for some radiosensitive ecosystems were reached. These lethal effects were seen in the coniferous forests in the nearest areas and for some small mammals.

Severe direct effects of high radiation doses were observed in some individual animals, but were not necessarily significant in changing the overall health of the population. For example, cows grazing contaminated pastures near the reactor in the early phase after the accident received thyroid doses in the range of hundreds of Gy, resulting in atrophy and total necrosis of the thyroid. For other ecosystems, individual plants, and animals, no lethal effects were observed.

In most cases, the plant and animal populations affected by radiation returned to normal in a few years. An example of this can be seen in a 3000-hectare region around the plant by 1988–89 the damaged conifers had recovered their reproductive functions, and today it seems likely that they will recover fully. Chronic dose rates in some areas within the 30-km exclusion zone may have reduced the fertility of animals of some species but it appears that other affected animal populations have already recovered. The significance of the observed changes in the long-term health of the specific populations is difficult to determine at this time.

There were media reports of severe birth defects in agricultural animals outside the 30-km zone in 1988–89, however, the frequency of these reported defects was shown to be similar in highly contaminated and non-contaminated regions of Ukraine, leading to the conclusion that the defects were not due to increased radiation dose. There have been no further reports of severe effects observed in farm animals.

There have been some reports of damage to mitochondrial chromosomes that have been passed on to subsequent offspring in high dose rate areas, but other evidence supports general recovery from the radiation damage. Today, there is no general consensus on potential long-term hereditary impacts on plants and animals where the doses were very high.

After 10 years, the major contributors to the low-dose chronic radiation are the remaining caesium radionuclides. The external dose in some isolated spots can still be of the order of 1 mGy per day; however, even in the 30-km zone, the natural environment seems to be recovering. Owing to the relocation of people from the 30-km zone, there have been some changes in the numbers and variety of animal and plant communities, but these changes have resulted from disuse of the land, not from radiation effects. Some natural populations have thrived as a result of the lack of human interference. No evidence has been found that any plant or animal species have been permanently eliminated from the most contaminated areas, except where clean-up activities involving soil removal have drastically altered the ecosystem.

Contamination in the environment. In the semi-natural environment, the key factors controlling the migration of radionuclides from topsoil into plants in meadow ecosystems are the clay and organic content of the soil and soil moisture. In general, the current migration rate is slow and steady and is expected to continue over the coming decades, even as the level of radioactive material in the soil declines. The transfer of strontium-90 is faster than for caesium-137, but the influence of the different types of soil is similar. This rate of transfer is an important consideration in the decisions regarding the long-term use of meadows as cow pastures.

Today, nearly all the contamination in forest ecosystems is found in the topsoil. The radiocaesium in trees is concentrated in the new growth rings owing to the transfer from the soil through the roots. This is not a significant problem but will increase the caesium-137 concentration in wood. No cost-effective countermeasure to reduce this transfer has been found.

Game animals that graze in semi-natural pastures, forests or mountainous areas, and wild foods consumed by people, such as berries and mushrooms, will continue to show elevated caesium-137 levels over the next decades. These foods may still be contaminated above the strict nationally adopted limits in areas of Belarus, Ukraine, and Russia, as well as in Nordic countries and the United Kingdom. The caesium-137 in these areas will remain available to be transferred into food products for a longer time period than in agricultural environments.

Since 1986, in the agricultural environment, effective application of countermeasures resulting in significant reductions of caesium and strontium into food has been demonstrated. The level of contamination, type of soil, soil moisture, and crop type are important influencing factors. For example, depending on the type of soil, the transfer factor between pasture and milk varies by several hundred, clearly illustrating that the proper application of these actions are very site specific. Relatively simple, inexpensive and successful agricultural countermeasures include: deep ploughing of surface contaminated soils; addition of fertilizers or other chemicals to agricultural lands; change in crop type; changing feeding regimes and slaughtering times of cattle; the use of impregnated "Prussian Blue" salt licks and boli to reduce the transfer of caesium to cattle; and relocation of animals to uncontaminated pastures. *(See related article in this edition, page 38.)*

Aquatic ecosystems have been shown to be tolerant of the radioactive contamination that gradually concentrates in the sediments. Even in the cooling pond of the Chernobyl power plant, only certain populations were affected, and no long-term direct radiation effects have been documented. The amount of radioactive material that found its way into freshwater aquatic systems was small compared to the total amount deposited. The surface water activity levels fell dramatically within one month of the accident. The public's perception notwithstanding, current contamination levels in reservoirs are well below the criteria that indicate a degradation in water quality. Fish, however, may accumulate radionuclides and countermeasures may be necessary in some places (even in countries far away, such as Sweden).

Conclusions. It can be concluded that at high radiation levels the natural environment showed short-term impacts in some high dose rate areas but existence of significant long-term impacts remains to be seen; and that effective countermeasures can be taken to reduce the transfer of contamination from the environment to the human population but these are highly site specific and must be evaluated in terms of practicality. If agricultural countermeasures are appropriately implemented, the main source of future doses will be due to the gathering of food and recreational activities in natural and semi-natural ecosystems. ❒