Science
Vol 233

The Aftermath of Chernobyl

Experts are divided on the long-term impact of the catastrophe on cancer mortality; the dispute reflects a long-standing disagreement on the risks of low-level radiation

It took less than a minute for a runaway reaction to destroy the unit IV power plant at the Chernobyl atomic energy station in the Soviet Union on 26 April. But the impact of the catastrophe on public health and the environment could last for decades, according to an official Soviet report on the accident and analyses by western experts.

The report, a detailed account of what caused the accident and of its immediate consequences, indicates that the explosion put almost 100 million curies of radioactivity into the environment, half of it in the form of relatively long-lived isotopes. The region around the plant itself is heavily contaminated, presenting a daunting clean-up problem. But fallout has affected a vast area of the western Soviet Union and Europe, giving low doses of radiation to millions of people.

An intense dispute has erupted over just how serious the long-term impact of this contamination is likely to be. The debate has reopened long-standing disagreements about the hazards of low-level radiation, and has resulted in wildly varying estimates of the number of cancer deaths that are likely to occur over the next few decades as a result of exposure to the fallout. They range from a few thousand to more than 100,000 fatalities.

The true figure will never be known, for even these large numbers will not be detectable among the background cancers in the millions of people exposed. Even the most pessimistic projections would raise overall cancer mortality in the western Soviet Union by only 1%.

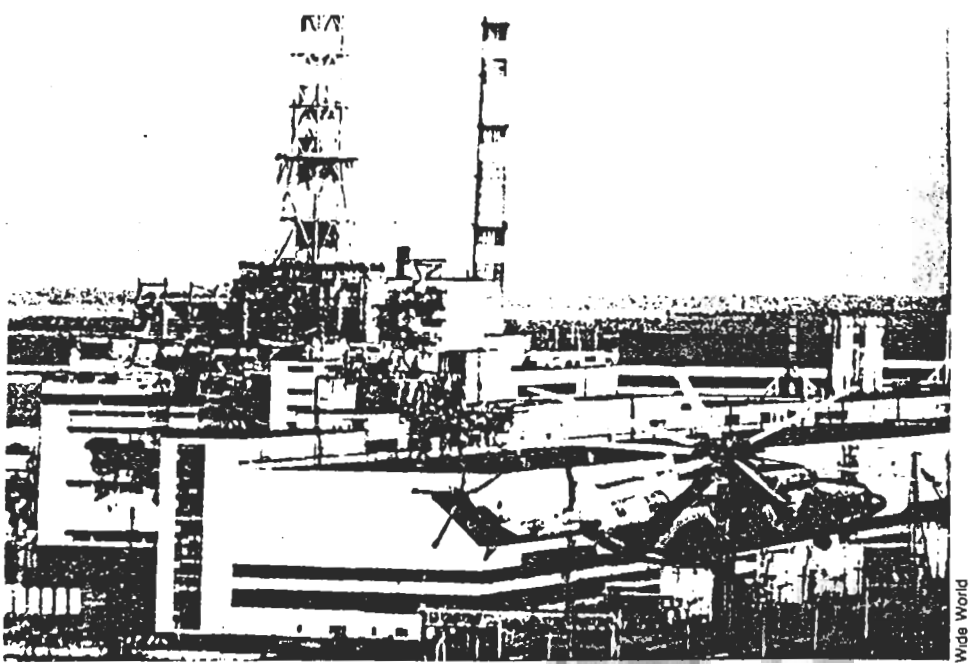
Disagreements over how to interpret the fallout data were evident at an unprecedented meeting, held by the International Atomic Energy Agency (IAEA) in Vienna on 25–29 August, at which Soviet experts discussed the accident with some 500 scientists, engineers, and nuclear energy officials from other countries. But delegates to the meeting were agreed on at least one point: the Chernobyl disaster offers a unique opportunity to gain a better understanding of the effects of radiation on a large population. As one British representative put it, the accident has provided conditions for a vast human experiment.

There is also general agreement, both among delegates to the meeting and radiation experts in the United States, that the report provides an impressive amount of information on radiation exposures to Soviet citizens. Although there are inevitable gaps in the information, the radiation data are "better than we had a right to expect," says Warren Sinclair, president of the U.S. National Council on Radiation Protection and Measurements (NCRP).

The report presents data only on fallout and exposure within the Soviet Union, however. Some observers have argued that total cancer estimates should be raised by up to 50% to include additional mortality in Europe.

The report indicates that the accident occurred when the reactor surged out of control during a test that was being conducted with many safety systems turned off (*Science*, 5 September, p. 1029). The initial explosion and fire sent 12 million curies of radioactivity into the environment during the first 24 hours and another 38 million curies were ejected over the following 10 days. (The report also estimates that an additional 45 million curies of radioactive xenon escaped from the devastated plant. Although this will have delivered large radiation doses to people in the immediate vicinity, xenon is not considered a long-term problem because it is an inert gas with a short half-life of about 9 hours.) In contrast, the Three Mile Island accident is reckoned to have resulted in the release of just 15 curies.

Radiation levels rose quickly around the plant and 135,000 people living within 30 kilometers of the site were evacuated during the 10 days following the explosion. They have not yet been allowed to return to their homes and may not be permitted to do so for perhaps another 4 years, the report indicates. This population, which received relatively large doses of radiation, will be the prime subjects for follow-up studies. Most of the discussion of overall cancer mortality has, however, centered on the 75 million people in the western Soviet Union who are



Wide World

The devastated plant. *An initial explosion tore the reactor apart and a second blast destroyed the roof of the building, releasing 100 million curies of radioactivity over 10 days.*

exposed to low levels of radiation from the fallout.

Calculating the excess cancer deaths arising from the accident requires two key steps, both of which are subject to large uncertainties. The first is an estimate of the average radiation exposure, and the second is to translate exposure into cancer risk.

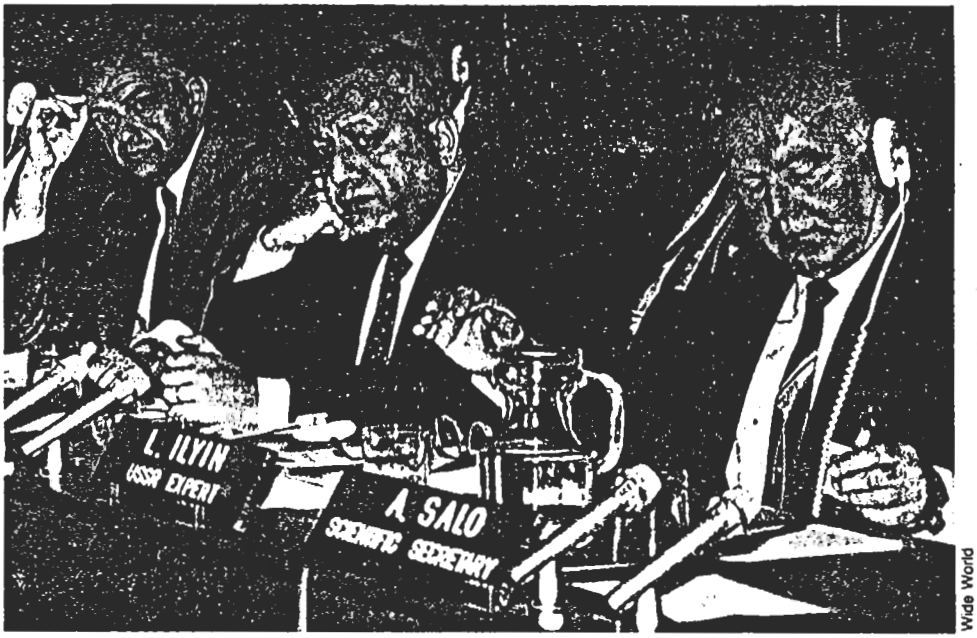
The report estimates that the accident will approximately double the average external exposure to radiation in 1986 among Soviet citizens living in the path of the fallout. Natural background radiation will result in an exposure equivalent to 10 million person rems, while the fallout from Chernobyl is expected to add another 8.6 million person rems. Radiation levels will decline as radioisotopes decay, but the fallout will continue to add to background levels for decades. Over the next 50 years, the total additional external exposure resulting from the accident will be equivalent to some 29 million person rems—less than 10% of the background over that period—the report estimates.

Calculations presented in the report indicate that this level of external exposure will increase the death rate from cancer in the region by a maximum of 0.05%. This would add about 5000 to the 9.5 million people who would normally be expected to die from cancer in the next 70 years.

In addition, internal radiation resulting from eating and drinking contaminated materials will add to background exposure. Two isotopes will dominate this additional internal dose—iodine-131 and cesium-137. Iodine, which tends to be concentrated in milk products and lodges in the thyroid gland, will be important over the near term. With a half-life of about 8 days, iodine-131's radioactivity decays relatively rapidly. However, cesium-137, which has a half-life of 30 years and lodges in soft tissue will dominate long-term effects—surprisingly so, if calculations in the report are correct.

Exposure to iodine-131 will not be uniform because it will depend on how much contaminated milk people drank. Although limits were placed on the amount of radioactivity permitted in milk that reached the market, the report acknowledges that many people consumed locally produced dairy products that exceeded the limits by factors of up to 200. As a result, some have received doses to the thyroid reaching "hundreds of rads," and the death rate from thyroid cancer in the affected region could increase by 1% over the next three decades, the report states. That would amount to some 1500 additional deaths.

As for cesium, the report has some relatively pessimistic conclusions. Because the soils in part of the fallout zone are poor in humus, cesium uptake in plants may be 10 to 100 times greater than in other soils. As a result, these regions "can expect relatively stable and high levels (almost at the current) of cesium-137 in food products in subsequent years." On the basis of what the report describes as "preliminary, purely speculative estimates of the contamination levels of food products," the report calculates that cesium-137 from the accident will result in an aggregate dose of 210 million person rems over 70 years. This would raise the cancer death rate by at most 0.4% and result in some additional 40,000 deaths, the report suggests.



Wide World

Discussing the medical implications. *Morris Rosen (left), Dan Beninson (center), and Leonid Ilyin. Rosen and Beninson presented their own cancer mortality estimates.*

The Soviet estimates were the subject of considerable discussion at the Vienna meeting, much of which took place in closed sessions. At a press conference on 26 August, Morris Rosen, director of IAEA's division of nuclear safety, said that on the basis of his own estimates, derived from exposure data in the report, he would expect an upper limit of about 25,000 extra cancers over the next seven decades, roughly half the Soviet projection. At the same press conference, Dan Beninson, director of nuclear licensing in Argentina and currently chairman of the International Commission on Radiological Protection, said he considered the Soviet figures "an extreme overestimate."

Rosen arrived at a lower figure than the Soviet report by assuming that fewer cancers are caused for a given dose of radiation. This so-called cancer risk factor lies at the heart of much of the debate about hazards from low-level radiation. In essence, the Soviet report assumed that every rem of additional exposure causes a maximum of 2 cancer deaths for every 10,000 people; Rosen's estimate was based on a risk factor of 1 in 10,000.

This use of a lower risk factor was immediately attacked by some other experts. For example, Thomas Cochran, a nuclear physicist with the Natural Resources Defense Council, called it "absurd." Cochran points out that the most recent report from the National Academy of Sciences' Committee on the Biological Effects of Ionizing Radiation (popularly known as the BEIR report) gave an upper limit of 5 cancer deaths per 10,000 for each additional rem. Applying that to the Soviet dose estimates gives a maximum of 100,000 fatalities, he says.

Others, including Seymour Jablon, a radiation expert at the National Academy of Sciences, and Warren Sinclair of the NCRP, believe that a factor of 2 per 10,000 is reasonable.

Two days after they made their estimate, Beninson and Rosen came up with even lower figures, however. Beninson said the total number of excess deaths might be as low as 5,100, while Rosen offered 10,000 as the most likely estimate. Both said they have revised their estimates downward because they believe the dose levels, particularly from internal radiation from cesium-137, may have been overestimated.

These conflicting figures indicate clearly the problems of piling uncertainty on uncertainty in the calculation of a mortality level that cannot itself be detected above the background. It also indicates the need for a more empirical basis for making the calculations. The Chernobyl accident may, however, offer a unique opportunity to gain the kind of empirical data that is needed.

The 135,000 people evacuated from the 30-kilometer zone represent a population roughly equivalent in size to the survivors of the atomic bombs dropped on Nagasaki and Hiroshima, who have been followed for four decades. Data from the atomic bomb survivors provide much of the basis for current cancer risk estimates.

From a scientific point of view the most important group to study may be the 24,200 people evacuated from within 15 kilometers of the plant. According to Soviet data, they received radiation doses ranging from 35 to more than 50 rems, a level of exposure that is likely to result in a statistically significant increase in cancer mortality. According to rough calculations performed by Jablon, application of the range of risk factors in the BEIR report indicates that excess cancer deaths in this population will be between 130 and 625 (a range that says a lot about the uncertainties).

Any long-term follow-up will require accurate assessments of individual doses. Soviet scientists have already distributed cards to the evacuees asking them to describe where they were at the time of the accident, but accurate dose estimates will require a battery of complex and costly cytogenetic tests. These are aimed at detecting chromosome aberrations, which correlate with degree of exposure.

Several suggestions were put forward privately at the meeting for an international effort to conduct the cytogenetic analyses, and various mechanisms to provide international advice on conducting the follow-up studies were discussed. No formal agreements were reached, however.

One concrete development that has occurred since the accident is that Soviet officials have decided to modify some features of the type of reactor that exploded at Chernobyl. Valeri Legasov, the head of the Soviet delegation to the meeting, said that about half the 27 reactors of the Chernobyl design are currently shut down for temporary fixes. These will include the addition of controls that will make it impossible for operators to override safety systems.

In addition, the reactors will be equipped with a safeguard to ensure that control rods are partially inserted in the core at all times. One of the major contributing factors in the Chernobyl accident was that virtually all the control rods were withdrawn in an effort to stabilize the power output before the experiment. Finally, in order to reduce the possibility that the power output from the reactors can surge uncontrollably, Soviet reactors will eventually use more highly enriched fuel. ■

COLIN NORMAN, *Washington*
DAVID DICKSON, *Vienna*