# Estimate of the Risk of Leukemia to Residents Exposed to Radiation as a Result of a Nuclear Accident in the Southern Urals

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**The results of a long-term investigation of the health consequences of radioactive environmental contamination from a military nuclear plant in the southern Urals are presented. The study population consists of 28,000 people, living on the Techa River downstream from the plant, who received substantial doses of external and internal irradiation from 1950 through 1956. The data on leukemia, one of the late effects of radiation, are presented. The upper limit of the range of cumulative absorbed doses in red bone marrow is estimated to be 3 to 4 Gy. Over 32 years, 37 cases of leukemia were observed among the exposed population. The increase in the incidence of leukemia compared with the incidence in two unexposed control groups was statistically confirmed. The majority of the excess cases of leukemia occurred from 5 to 20 years after the beginning of irradiation and are both acute and chronic granulocytic in type. On the basis of the data, the absolute risk of developing leukemia is estimated to be 0.48 to 1.10 per $10^4$ person-years-gray.** [PSRQ 1992;2:187-197]

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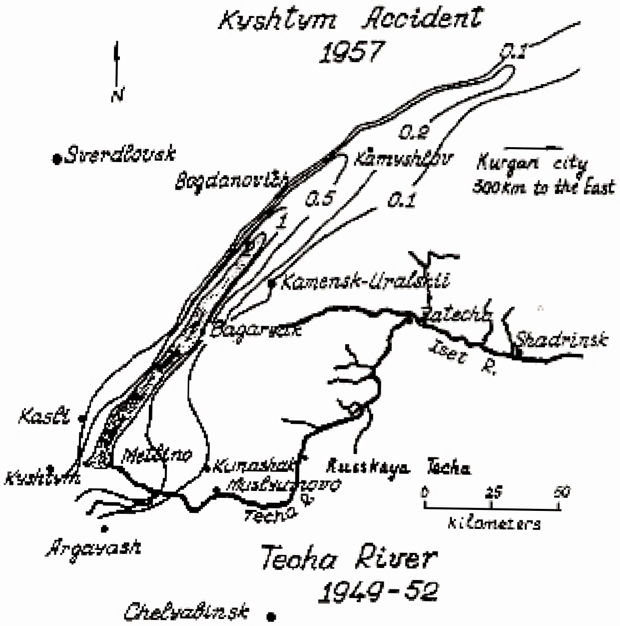

**FIGURE 1.** Region in which radioactive environmental contamination occurred. Contamination lines indicate the levels for strontium-90 in curies per square kilometer in 1957 and 1958, shortly after the Kyshtym accident. The Techa River is traced from its source near the secret nuclear plant to where it feeds into the Iset River.

The assessment of the risk of late-stage somatic effects of ionizing radiation is based primarily on the results of epidemiological investigations. The major sources of data on radiation carcinogenesis in humans include atomic bomb survivors, patients irradiated therapeutically to treat cancers or other diseases, and individuals involved in nuclear accidents [1]. There are many problems in the assessment of risk, the primary one being how to extrapolate the results obtained at high doses and dose rates to low levels of exposure. This study of the consequences of this early nuclear accident in the southern Urals contributes to resolving this problem of extrapolation.

There were two incidents of massive radioactive environmental contamination from a secret military nuclear plant in Chelyabinsk Region that led to the exposure of the population living in the area. The first incident, the effects of which are investigated in this study, resulted from the disposal of radioactive wastes into the Techa River from 1949 through 1956. It was thought that the water would dilute the waste and render it harmless. The second occurred in 1957 when radioactive materials were released as a consequence of an explosion in a storage tank (installed to replace the river disposal system) containing high-level radioactive waste (the Kyshtym accident).

The area most affected by the first two incidents includes parts of Chelyabinsk, Kurgan, and Sverdlovsk (Ekaterinburg) Regions (Fig 1). Key characteristics of these two incidents are given in Table 1. Study of the population exposed as a consequence of the first incident, the contamination of the Techa River, began in 1951 and still continues. Results relating to leukemia morbidity and mortality as of the end of 1981 are presented here with a focus on estimation of risk.

## DOSE ASSESSMENT METHODS AND ENVIRONMENTAL EXPOSURE FOR THE TECHA RIVER INCIDENT

For a study to contribute to the evaluation of radiation risk, it must include the type of radiation and the dose levels received by those exposed. Because no one was wearing a dosimeter, we had to reconstruct the doses received. How we determined the radiation and dose levels is explained below.

The dynamics of radioactive dispersal and isotopic composition of the Techa River are shown in Figure 2. The most radioactivity was released in 1950 and 1951. In 1949, there were 28,000 people living in 38 villages along the banks of the Techa River. These villages were situated for 237 km downstream from the secret military plant. For many of these people, the Techa River was their main source of drinking water. From 1953 to 1961, 7,500 residents from the upper reaches of the Techa were resettled. The source of drinking water for those remaining in 1956, including 4,950 residents who would be resettled by 1961, was transferred to underground systems entirely separate from the river (the wells were tested for radionuclides), and the radioactive contaminated riverside was fenced off. From 1950 to 1961, however, the inhabitants of the Techa riverside villages received substantial doses of both chronic external and internal irradiation.

### *Estimates of External Irradiation*

The measurements of gamma dose rate along the riverbank (Fig 3), on the shore within a few hundred meters of the water, in specified areas of villages, and inside houses were used to estimate the absorbed doses of external irradiation. We obtained these measurements from the technical reports of a special team (led by Professor Alexander Marey)

**Table 1. Comparison of Nuclear Incidents in the Southern Urals**

| Main Characteristics | Techa River | | Kyshtym Accident | |
|---|---|---|---|---|
| Released activity (Ci) | $3 \times 10^6$ | | $2 \times 10^7$ | |
| Type of release | Aquatic | | Atmospheric | |
| Isotopic composition as percentage of release | $^{89}Sr$, $^{90}Sr$ | 20.4 | $^{90}Sr$ | 5.4 |
| | $^{137}Cs$ | 12.2 | $^{144}Ce$ | 66.0 |
| | $^{95}Zr$, $^{95}Nb$ | 13.6 | $^{95}Zr$, $^{95}Nb$ | 24.9 |
| | $^{103}Ru$, $^{106}Ru$ | 25.9 | $^{106}Ru$ | 3.7 |
| | Rare-earth elements | 26.9 | | |
| Type of irradiation | | | | |
| External | From contaminated sediments and soils | | From deposited radionuclides | |
| Internal | From intake of river water and milk ($^{90}Sr$, $^{89}Sr$, $^{137}Cs$) | | From intake with contaminated foodstuffs ($^{90}Sr$, rare-earth elements) | |
| Size of exposed population | 28,000. This is the number of people who lived in the Techa riverside villages in 1949–1952. The whole population is under observation. | | 34,000. This is the part of the population exposed as a result of the Kyshtym accident. These people lived on the most contaminated territories and are under observation. | |
| Distribution of doses to red bone marrow | | | | |
| Mean (Gy) | 0.4 | | 0.02 | |
| Range of individual doses (Gy) | 0–4.0 | | 0–0.9 | |

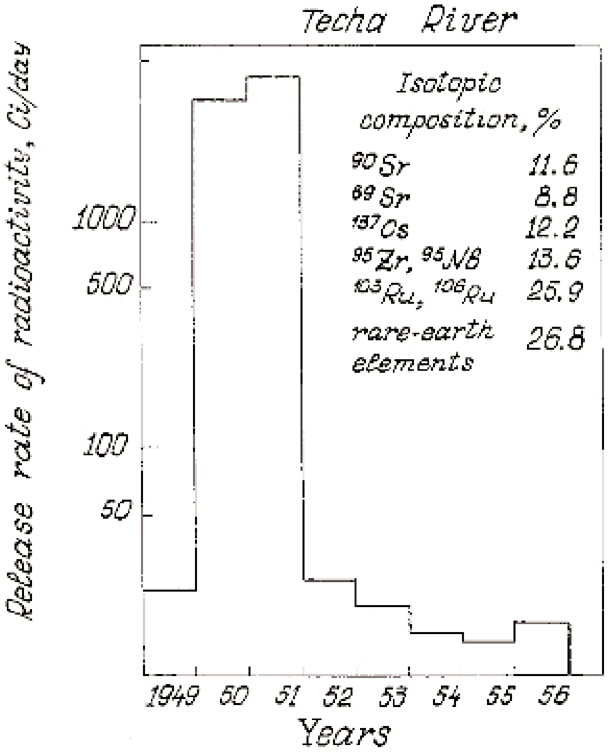

**FIGURE 2.** The average amount of radioactivity released per day into the Techa River from 1949 through 1956 and the isotopic composition of the release. Because of methods used to round off numbers, the number for rare-earth elements does not agree with the number in Table 1. Ci = curie.

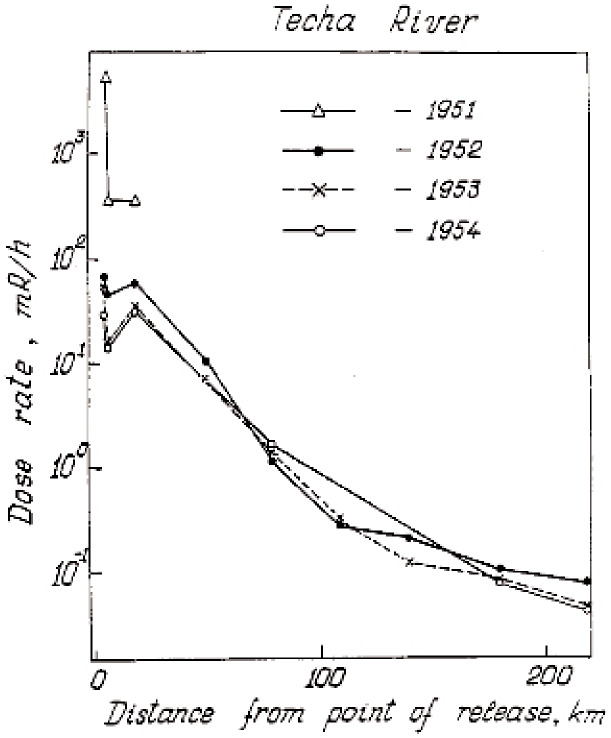

**FIGURE 3.** Results of dose-rate measurements along the riverbank in the early 1950s. (Data were obtained from the technical reports of special teams [led by Professor A. Marey] from the Institute of Biophysics of the U.S.S.R. Ministry of Health.) mR/h = milliroentgen per hour.

from the Biophysics Institute of the U.S.S.R. Ministry of Health. Unfortunately, these reports do not provide enough detail to judge the accuracy of the measurements, but there are no other data on gamma radiation along the Techa River during the early 1950s. The measurements were begun in the summer of 1951 along the upper reaches and since 1952 were made regularly along the whole Techa River. These measurements were taken once a year along the whole Techa River and two to five times a year in specific reference sites along the upper reaches of the Techa. On the basis of these measurements, we reconstructed the average annual levels of exposure for the most commonly used sites in each of the riverside villages.

The evaluation of periods of time the people stayed in each of these specified sites with different dose rates was made by Professor Melkhior Saurov from the Institute of Biophysics by monitoring typical modes of life of different age groups of inhabitants from the riverside villages.[1] Such an approach gave an opportunity to record the average annual absorbed doses from external radiation for each village and for every age group in each village.

Accumulation of doses from external radiation for all practical purposes stopped after 1956 when all inhabitants of the upper Techa River were resettled and the contaminated floodplain of the lower Techa River was fenced off. Average cumulative doses of external radiation are given for the populations of the villages (adjusted for age distribution), plotted against their distance along the river downstream from the site of the release of the radioactive wastes (Fig 4).

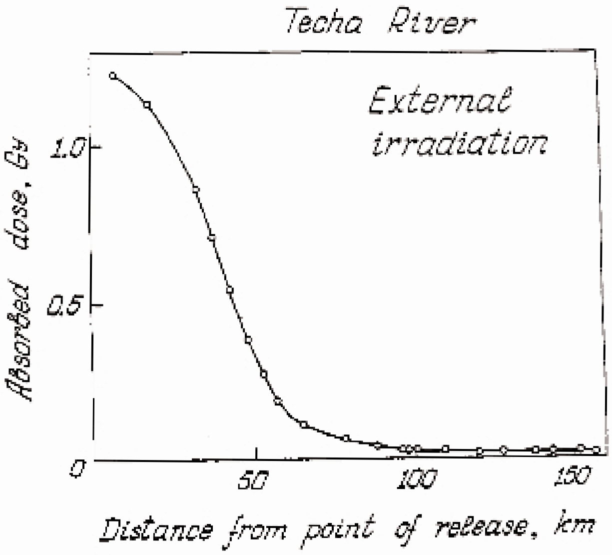

**FIGURE 4.** Average whole-body absorbed doses for the residents of Techa River villages at various distances from the point of release of the radioactivity. Gy = gray.

### *Estimates of Internal Radiation*

To calculate the tissue doses of internal radiation, it is necessary to know the dynamics of the accumulation of radionuclides in organs and tissues of an individual. The main dose-forming radionuclide released into the Techa River and ingested by humans was strontium-90, which is accumulated and stored for a long time in bone (the half-life of strontium-90 is 10,000 days). Beginning in 1960, specialists from Branch Number 4 of the Institute of Biophysics in Chelyabinsk (now named the Urals Research Center of Radiation Medicine) have measured the surface beta-activity of teeth. Since 1974, they have checked the inhabitants of the Techa River area with the whole-body counter SICH-9.1 to determine how much strontium-90 (in the skeleton) and cesium-137 (in soft tissues of the whole body) these people had absorbed [2–4]. More than 12,000 inhabitants, those who were exposed and had remained in Chelyabinsk and Kurgan Regions, have been measured since 1974 when the whole-body counter was developed.

Results of numerous measurements showed that there was a clear correlation between the age of the person and the amount of $^{90}$Sr measured in his or her bones and tooth enamel (Fig 5). To account for this correlation in dose assessment, Degteva and Kozheurov [5] developed an age-dependent model of the retention of strontium in human bones. The model takes into account the changes in mass of the skeleton, metabolic changes, and the structure of bone depending on age.

In addition to the data about long-term retention of $^{90}$Sr from the Techa River incident, information about the content of $^{90}$Sr in the bones of people of other regions as the result of global fallout and experimental results of instantaneous injection of $^{85}$Sr into humans [6] were used to reconstruct doses absorbed. For a 40-year-old adult male human, the elaborated model corresponds to the adult male

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[1] Professor Saurov studied patterns of human activity. He fixed the time that adults, teenagers, or children spent at home, in other buildings (work or school), in the fields, in the streets, or along the riverbank. From these data, he calculated the average time spent in these specific sites by children, teenagers, and adults.

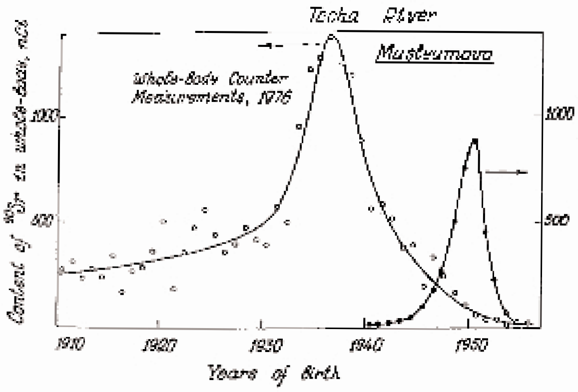

**FIGURE 5.** Whole-body counter measurements and beta-counts of teeth of residents in Muslyumovo (Data are from Vyacheslav P Kozheurov.) Open circles = average values of strontium-90 content in the whole body for different age cohorts; filled circles = average values of beta-counts per minute of teeth for age cohorts of younger segment of the population only; left curve = age dependence of strontium-90 for the population of the village of Muslyumovo calculated with the help of Degteva and Kozheurov's model (those born in 1935 through 1937 have the highest whole-body content of strontium); right curve = age dependence of beta-count of the teeth (those born about 1950 have the highest content in their teeth). nCi = nanocurie ($10^{-9}$ curie).

model in Publication 20 of the International Commission on Radiological Protection (ICRP) [7] Such a method enabled us to offset to some extent the absence of reliable information about the initial period of exposure in the Techa River area. Degteva and Kozheurov calculated absorbed doses in the red bone marrow (RBM) and in cells on bone surfaces [5] by using models from Spiers and colleagues [8] and Le Grand [9].

Vyacheslav Kozheurov reconstructed the $^{90}$Sr ingestion rates of the residents by using the dosimetry of teeth (based on what we know about the uptake of strontium-90 during the development of teeth). The enamel of front molar teeth is formed during a short time, but the replacement breakdown metabolism of enamel takes a long time. Information about the content of $^{90}$Sr in tooth enamel of the population age groups in which formation of enamel took place during the period of massive releases can adequately show the dynamics of intake in that period The retrospective evaluation of the ingestion of $^{90}$Sr by humans is based on this concept Because radionuclides entered humans primarily through the ingestion of drinking water and water used in food preparation, the intake levels of other radionuclides were estimated on the basis of the nuclide composition of the river water and the estimated intake levels of $^{90}$Sr as derived by the methods described.

Previous assessment of internal doses on the basis of the ICRP adult human male model and the average intake levels for adults from the Techa River area showed that almost all internal irradiation was from $^{90}$Sr, $^{89}$Sr, and $^{137}$Cs. We used these three radionuclides for internal dose estimates. An age-dependent model used for $^{137}$Cs was close to one from ICRP Publication 56 [10].

The mean doses in RBM for different villages are shown in Figure 6. These assessments are based on calculated doses of external irradiation and on individual doses of internal irradiation determined by whole-body counter measurements of strontium-90 in 12,000 people in the affected villages The equivalent doses in RBM were calculated by using a model created by Degteva and Kozheurov [5]. The scattering primarily reflects the proportion of people who drank well water or river water in 1950 to 1951, which differs in different villages.

The average values for cumulative (external plus internal) organ-absorbed doses for the inhabitants of selected villages are given in Table 2, and the dynamics of dose accumulation in RBM are shown in Figure 7. The inhabitants of the villages accumulated 80% to 95% of committed lifetime dose within the first 10 years. By using our estimate of RBM dose levels, we determined that 74% of the overall population was exposed to less than 0.5 Gy of radiation; 8% was exposed to more than 1.0 Gy

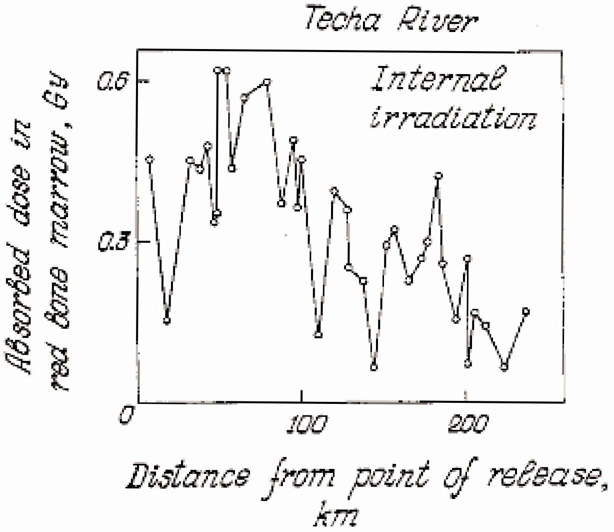

**FIGURE 6.** Mean absorbed doses of radiation (adjusted for age) to the red bone marrow of residents of Techa River villages at various distances from the point of release of the radioactivity. Gy = gray

**Table 2. Organ Dose Estimates (External Plus Internal) for Inhabitants of Select Villages of the Techa Riverside**

| Village | Distance from the Site of Release (km) | Mean Absorbed Doses (Gy) | | | | |
|---|---|---|---|---|---|---|
| | | Red Bone Marrow | Bone Surface | Upper* Section of Large Intestine | Lower* Section of Large Intestine | Other† Organs and Tissues |
| Metlino | 7 | 1.64 | 2.26 | 1.33 | 1.46 | 1.27 |
| Muslyumovo | 78 | 0.61 | 1.43 | 0.21 | 0.37 | 0.12 |
| Russkaya Techa | 138 | 0.22 | 0.53 | 0.07 | 0.13 | 0.04 |
| Zatecha | 237 | 0.17 | 0.40 | 0.06 | 0.11 | 0.03 |

* The model from Publication 30 of the International Commission on Radiological Protection was used to determine the doses to the gastrointestinal tract.

† "Other organs" means all internal organs except for the four mentioned in the table.

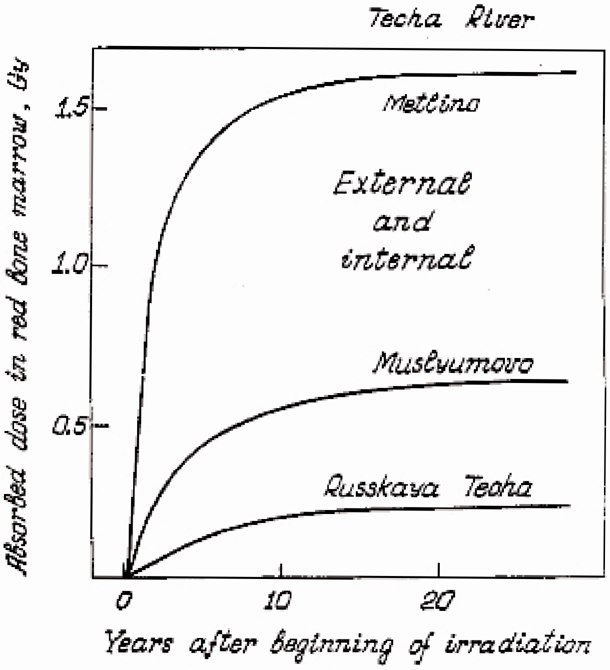

**FIGURE 7.** Mean absorbed doses of radiation (adjusted for age) over time in red bone marrow of residents of three Techa River villages: Metlino (7 km from the point of release), Muslyumovo (78 km from the point of release), and Russkaya Techa (138 km from the point of release). Gy = gray.

of radiation; and about 1% received more than 2.0 Gy. Our preliminary estimate of the upper limit of the range of cumulative equivalent individual doses is 3 to 4 Gy.

## TECHA RIVER REGISTER

To carry out long-term epidemiological studies, the Techa River Register was created. It contains the names and medical data of 17,000 people who resided in the Techa riverside villages in Chelyabinsk Region and of 11,000 people who resided in the riverside villages in Kurgan Region, covering both populations from 1949 through 1952. In addition, the register is regularly updated with newly obtained information on individuals lost to follow-up because of migration or death. The register enabled us to obtain the number of people followed for each year analyzed.

The risk of leukemia is based on morbidity and mortality data.

### *Morbidity Data*

The information on the incidence of leukemia was obtained from two sources. The first source was case histories obtained from the clinical department of Branch Number 4 of the Biophysics Institute, which has functioned since 1967 as the hematological center serving four districts of Chelyabinsk Region. These districts include the districts that the Techa River flows through and the districts in which the residents of the riverside villages were resettled (the Kunashaksky, Krasnoarmeysky, Argayashsky, and Sosnovsky districts). Irradiated persons make up about 30% of the population of these districts. The existence of one hematological center ensured access to hematological patient registration and uniformity of criteria used in the classification of the type of leukemia in the exposed and nonexposed populations from these districts. The second source was the Cancer Register of the Regional Oncologic Dispensary, which registers all newly detected malignant tumors including lymphatic and hematopoietic tissue neoplasms.

Diagnoses were verified by clinical and laboratory studies (including bone marrow studies) and cytochemical and cytogenetic analyses (since the 1960s), as well as pathological examination.

Coding for the type of leukemia for a computerized database and epidemiological studies was done according to the *Manual of the International Statistical Classification of Diseases, Injuries, and Causes of Death* [11].

To assess the level of radiation exposure in terms of significant risk for developing leukemia, the leukemia morbidity rate for the exposed population was compared with that of the control groups. To improve the reliability of the results, two control groups were established. Control group 1, observed for 10 years, includes 343,000 people, the population of all the rural districts of Chelyabinsk Region except the four districts in which the irradiated population resides. Information on the leukemia morbidity of this population is available for 1972 through 1982. Control group 2 includes 52,000 people, the nonexposed population of two rural districts (Krasnoarmeysky and Kunashaksky) through which the Techa River flows. The follow-up period for this second control population is 1952 through 1958. Control group 2 has fewer people than control group 1, but it matches the exposed population more closely for such characteristics as residential area, the quality of medical service, and ethnic background.

Since the control populations comprised individuals matched for age (born before 1953) with those who were irradiated, age-specific incidence standardization was not necessary. Morbidity data are given in Tables 3 and 4.

### *Mortality Data*

Investigators at Chelyabinsk Branch Number 4 of the Biophysics Institute studied mortality in the exposed population independently of their study of the incidence of leukemia. The separation of the two studies resulted in some differences in "dose groups" used in the two studies. The mortality study encompasses the population of both Chelyabinsk and Kurgan Regions that resided in the Techa riverside villages. This population tended to be heterogenous in the amount and level of their exposure to radiation, in other factors that influence carcinogenesis such as national and ethnic genetic factors, and in administrative regions in which they lived. To eliminate the influence of national/ethnic genetic factors and differences in health administration in the different regions, several control groups composed of nonexposed populations were used for comparing mortality rates. Each of the control groups was matched to the exposed group for nationality and administrative area of residence (Table 5). The information on mortality was obtained from governmental institutions that register deaths and births:

**Table 3. Leukemia Morbidity in the Techa River Study**

| | Observation Period (yr) | Number of Cases of Leukemia | Incidence per $10^5$ PY* | 95% Confidence Intervals |
|---|---|---|---|---|
| Exposed population | 32 | 37 | 10.6 | 7.1–14.1 |
| Control 1 (Chelyabinsk Region) | 10 | 133 | 4.5 | 3.7–5.3 |
| Control 2 (Kunashaksky and Krasnoarmeysky Districts) | 32 | 93 | 5.6 | 4.4–6.8 |

* PY = person-years

**Table 4. Leukemia Morbidity According to Exposure in the Techa River Study**

| Mean Dose to Bone Marrow (Gy) | PY* | Cases of Leukemia | Incidence per $10^5$ PY* | 90% Confidence Intervals |
|---|---|---|---|---|
| 1.43 | 46,777 | 6 | 12.8 | 5.6–25.3 |
| 0.82 | 36,339 | 3 | 8.3 | 2.3–21.3 |
| 0.59 | 90,909 | 9 | 9.9 | 5.2–17.3 |
| 0.29 | 106,808 | 12 | 11.2 | 6.5–18.2 |
| 0.13 | 108,047 | 7 | 6.5 | 3.0–12.2 |
| Control 1 | 2,956,000 | 133 | 4.5 | 3.9–5.2 |
| Control 2 | 1,664,000 | 93 | 5.6 | 4.6–6.6 |

* PY = person-years

**Table 5. Characteristics of the Observed Cohort and Mortality from Leukemia**

| Groups Under Observation | Length of Time on the Bank of the Techa After Exposure | Predominant Ethnic Group | Average Doses in Red Bone Marrow (Gy) | Number of PY* Under Observation | Number of Deaths from Leukemia | Leukemia Mortality Rate per $10^5$ PY* | 90% Confidence Intervals |
|---|---|---|---|---|---|---|---|
| 1 | 5–8 yr | Russians | 1.64 | 13,065 | 2 | 15.3 | 2.6–48.2 |
| 2 | 9–10 yr | Tartars and Bashkirs | 0.82 | 50,627 | 4 | 7.9 | 2.7–18.1 |
| 3 | Still reside | Tartars and Bashkirs | 0.61 | 61,850 | 4 | 6.5 | 2.2–14.8 |
| 4 | 10–12 yr | Russians | 0.29 | 32,250 | 3 | 8.5 | 2.3–22.0 |
| 5 | Still reside | Russians | 0.18 | 129,980 | 9 | 6.9 | 3.6–12.1 |
| 6 | Still reside | Russians | 0.18 | 131,303 | 5 | 3.8 | 1.5–8.0 |
| Control group 1 (compared with exposed groups 2 and 3) | — | Tartars and Bashkirs | — | 372,320 | 6 | 1.6 | 0.7–3.2 |
| Control group 2 (compared with exposed groups 1, 4, and 5) | — | Russians | — | 828,050 | 30 | 3.6 | 2.6–4.9 |
| Control group 3 (compared with exposed group 6) | — | Russians | — | 938,010 | 34 | 3.6 | 2.7–4.8 |

* PY = person-years

the Bureaus of Civic Status Registration of Chelyabinsk Region and Kurgan Region. The cause of death was coded according to the *Manual of the International Statistical Classification of Diseases, Injuries, and Causes of Death* [11].

The study deals only with leukemia mortality. The data on leukemia mortality are given in Table 5. The total number of leukemia mortality cases does not equal the total number of leukemia cases because some individuals with leukemia (both in exposed and in control groups) died of other causes. It is possible that this method of data collection led to our estimates of absolute risk being too low.

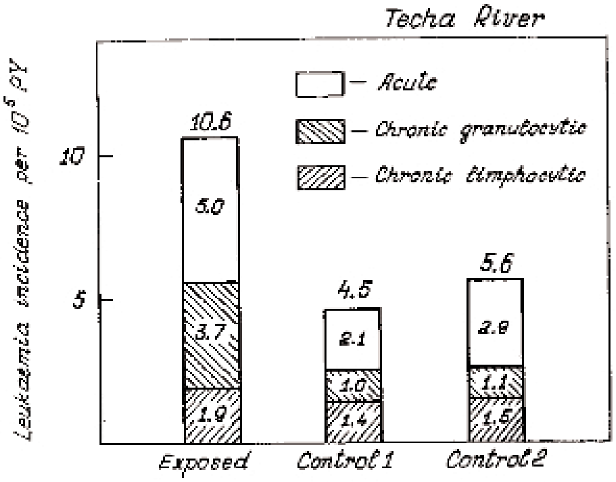

**FIGURE 8.** Type of leukemia found in exposed and control populations.

## RESULTS AND DISCUSSION

Analysis of the Techa River data shows a statistically confirmed increase of the incidence of leukemia in an exposed population compared with two control groups (see Table 3). The excess cases were primarily made up of acute and chronic granulocytic leukemia (Fig 8). Most of the excess leukemia cases were seen 5 to 20 years from the beginning of irradiation (Fig 9).

To determine whether there was a dose-response relationship, all exposed individuals were grouped by dose categories (see Tables 4 and 5). A correlation-regression analysis of these data shows a significant correlation in morbidity and mortality with dose (Fig 10). It is necessary to keep in mind, however, that we used standard tests of trend that rely on asymptotic approximations, which may result in exaggerated significance levels. Our analysis has also ignored the possibility of dose errors that can distort the regression line.

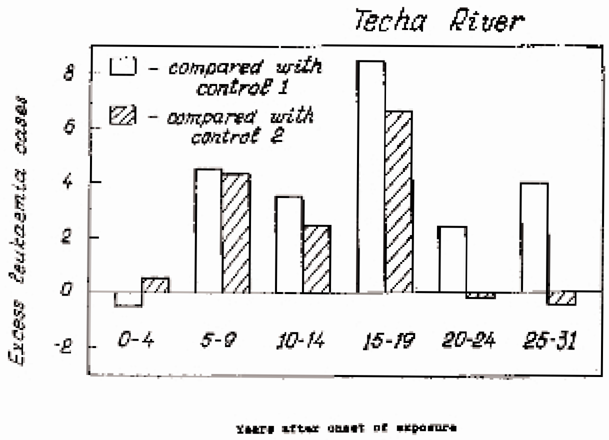

**FIGURE 9.** Excess leukemia incidence expressed in absolute numbers.

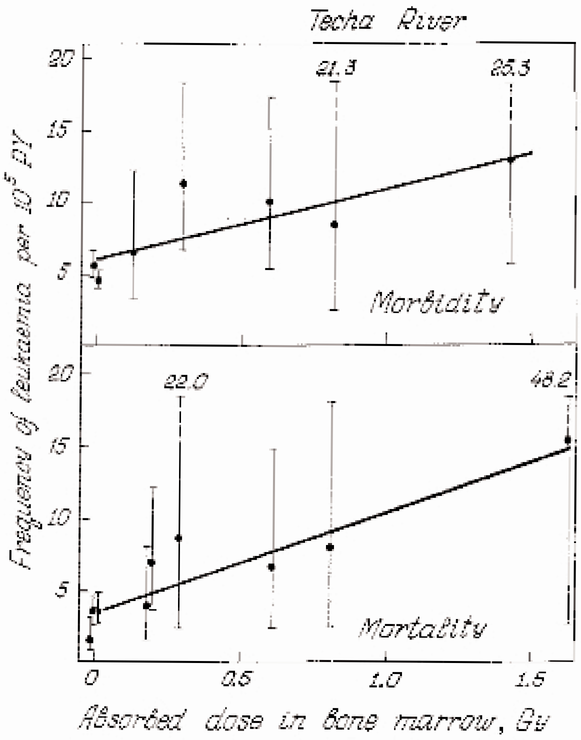

**FIGURE 10.** The dose-response relationship for leukemia morbidity and mortality. PY = person-years. Gy = gray.

The risk estimates given below are based on the concept of absolute risk and linear form of dose-response function. The versions of leukemia risk assessment are summarized in Table 6.

The first method of risk estimation is based on the total of excess cases of leukemia in the whole population (see Figure 9). The expression is

$$\mathbf{R} = \mathbf{n}/(\mathbf{N} \cdot \bar{\mathbf{D}}),$$

where **R** is (here and below) the absolute risk coefficient (per $10^4$ person-years-gray); **n** is the total number of excess cases; **N** is the number of person-years under observation; and $\bar{\mathbf{D}}$ is the average bone marrow-absorbed dose for all people (0.54 Gy).

The second and third methods are variants of the regression analysis. The second method of risk estimation may be written as

$$\mathbf{Y} = \mathbf{Y}_0 + \mathbf{RD},$$

where **Y** is the risk of leukemia, **D** is the variable bone marrow-absorbed dose, and $\mathbf{Y}_0$ and **R** are determined by application of the least-squares method from the data of Tables 4 and 5.

**Table 6. Estimate of Leukemia Risk Based on Techa River Data by Method Used**

| Method | Data | Absolute Risk per 10,000 PYGy* |
|---|---|---|
| Excess cases of leukemia | 1) 23 excess cases compared with control 1 | 1.10 |
| | 2) 14 excess cases compared with control 2 | 0.67 |
| Regression analysis of the dose-base incidence of leukemia | 1) Morbidity data | 0.48 |
| | 2) Mortality data | 0.68 |
| "Weighted"† regression analysis of the dose-base incidence of excess leukemia | 1) Excess morbidity when compared with control 2 | 0.68 |
| | 2) Excess mortality when compared with control groups from the same districts | 0.79 |

* PYGy = person-years-gray

† Weighting coefficients were created by taking the inverse of the confidence limits

It appears that the assessment of $Y_0$ overestimated real control rates (this can be seen from Figure 10), and consequently could underestimate risk coefficients. The third method used to estimate risk is one that uses the lengths of confidence intervals in the least-squares procedure. In this method, the sum of the squares of the deviations multiplied by "weighting coefficients" is minimized.

As can be seen in Table 6, all methods give values of risk coefficients between 0.48 and 1.10 per $10^4$ person-years-gray.

It is interesting to compare our study with similar investigations by other authors [12–14]. Table 7 compares the Techa River study with other studies that investigated the relationship between exposure to ionizing radiation and the risk of leukemia [12–14]. The risks in the Techa River study are smaller than the risks to atomic bomb survivors and those irradiated for treatment of ankylosing spondylitis and cervical cancer. Further study is needed because it is not possible to determine whether the smaller risks are the result of prolonged exposure to low-dose rates or whether the number of cases of leukemia is underestimated in the current study, this underestimation being the reason for the lower excess risk estimates. ❧

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**Table 7. Comparison of Leukemia Risk Studies**

| Main Characteristics | Techa River Study | Atomic Bomb Survivors [13] | Spondylitis Series [14] | Cervical Cancer Series [15] |
|---|---|---|---|---|
| Size of exposed population | 28,000 | 42,000 | 14,000 | 83,000 |
| Percentage of women in study | 56% | 59% | 17% | 100% |
| Age at irradiation (yr) | 0–>90 | 0–>90 | >15 | <30–>70 |
| Type of control | Regional rates and internal | Internal (34,000) | National rates | National rates and internal |
| Type of irradiation | Chronic, external, and internal: $^{90}$Sr, $^{89}$Sr, $^{137}$Cs | Instantaneous, whole-body | Fractionated, nonuniform, partial-body | Chronic, fractionated, partial-body |
| Type of dosimetry | Individual (internal) and mean doses in a village (external) | Individual | Individual | Mean dose of a sample |
| Dose distribution | | | | |
| Mean dose (Gy) | 0.40 | 0.24 | 1.9 | Extremely uneven |
| Range of individual doses (Gy) | 0–3.0 | 0.01–6.0 | 0–8.06 | |
| Person-years at risk | 422,000 | 1,134,000 | 184,000 | 623,800 |
| Absolute risk per 10,000 person-years-Gy | 0.48–1.10 | 2.94 (2.43–3.49) | 2.02 | 0.61 |

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**COMMENTARY**

# Response to the Paper of Kossenko et al.

David Rush, M.D.*

The scientific world was startled by the emergence of the data in part presented by Dr. Mira Kossenko and her colleagues in this issue of the journal. The Soviet authorities only first confirmed the 1957 Kyshtym explosion in 1987, 30 years after the event; then two years ago we first learned from Dr. Kossenko that the health of thousands of the victims of dumping of raw radioactive wastes from the Mayak plutonium processing plant near Chelyabinsk has been followed by the research unit she heads.

I was privileged to attend the International Radioecological Conference in Chelyabinsk in May of this year. I listened to most of the 30 or so papers presented by Russian scientists at the section on Medical Effects of Radiation Exposure. The translators were unaccustomed to technical terminology, and the slides were very difficult to understand. (They were shown on a screen four feet wide in an auditorium with about 1,000 seats.) Still, some generalizations were possible. There were many groups working on both worker and community health, in addition to Dr. Kossenko's; the levels of exposure were very much higher than those that have been reported from nuclear accidents or industry in the West; my impression (and, until these data are published, it will remain an impression) was that the reported health effects were surprisingly and uniformly low, given the high exposures, and that the research techniques and interpretations, having developed in isolation and in secret, were unpolished. Other relevant information included a remarkable documentary film in which residents in the villages studied by Dr. Kossenko stated that they were never told why they were of such interest, were never told that they had been exposed to radiation, and were never given the diagnoses of their diseases. Complaints were most often dismissed as caused by "dystonia," and death certificates were said to have been falsified. Further, when members of our group visited local hospitals, they were told of large numbers of dead and dying after the two acute disasters in 1957 and 1967 who were kept "off the books." We could not verify these stories, but they, and the attitudes of many of the senior bureaucrats in the nuclear weapons complex with whom we discussed what should be the future directions of health research, gave us pause. These managers asserted minimal, if any, health consequences from weapons production, much like their U.S. counterparts. (The persons in charge appeared to be those who directed the complex over the years, despite the political upheavals of the last few years.) They are hardly disinterested scientists; their professional futures, and conceivably their lives, might depend on the outcome of this research.

Nor is our Department of Energy a disinterested spectator to these events; a U.S. Department of Energy spokesperson, when discussing these data, said on National Public Radio:

> If our clean-up is required to go the very significantly low levels that are currently—we're currently driven to, it could cost the United States a trillion dollars or more. What we need to do is to establish very realistic standards that we can work towards. And we believe that that data only exists in one place on the planet, and that place is at Chelyabinsk [1].

Thus the Department of Energy has strong motivation to fund and participate in this research and has signed an agreement to do so [2]. And we must remain skeptical of both the research presented in this issue and what may appear in the future, unless

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the exposures, but far more importantly the outcomes, are independently verified by the families and caregivers, and not just the paper records, of the exposed. The stakes are very high, and the players are not necessarily without their own motives on how the results turn out. ❧

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