JCO accident at Tokai-mura

SS-II-1 Summary of JCO Criticality Accident & Dose Assessment
Shun-ichi TANAKA;
Tokai Research Establishment, Japan Atomic Energy Research Institute

The criticality accident occurred on September 30, 1999 in a conversion test facility at the JCO Tokai site gave serious radiation dose to 3 employees and fatal dose to 2 of the 3. Neutrons and gamma-rays emitted with the accident caused meaningful dose to the residents of the surrounding area. The accident triggered by pouring 18% enriched uranyl nitrate solution to a precipitation vessel beyond the critical mass had continued for about 19 hours before stopping the criticality, and emitted continuously neutrons and gamma-rays from fission reactions. Total number of fission reaction was 2.5x10^18, which was estimated by the activity analysis of fission products in solution of the precipitation vessel.

Dominant dose for the residents and the JCO employees was brought by neutrons and gamma-rays from the precipitation vessel, while the contribution of radioactive plume was negligible. The individual dose was estimated for 200 residents, 169 JCO employees and 60 emergency personnel. The maximum doses were 21mSv for the residents, 48mSv for the JCO employees, and 9.4mSv for emergency personnel, respectively. Subsequently, no deterministic influence has been observed except for the 3 workers.

SS-II-2 Cytogenetic study on weakly irradiated cases in Tokai-mura criticality accident.
Isamu HAYATA1, Masao SASAKI2, Yoshiaki KODAMA3, Nanao KAMADA4, Seiji KODAMA3;
1NIRS, 2RBC, Kyoto Univ., 3RERF, Hiroshima, 4RIRBM, Hiroshima Univ., 5Schl. Pharm. Sci., Nagasaki Univ.

Chromosome analysis of peripheral lymphocytes of the weakly exposed cases in the Tokaimura criticality accident was performed in collaboration with 5 Institutions noted above. Informed consent was obtained from 36 persons. Peripheral blood was drawn from them at Mito-city within 4 weeks after the accident. The blood kept in the cold preservation medium was brought to NIRS. The chromosome preparation was made according to the separated lymphocyte culture for the study of low dose estimation at NIRS. More than 200 cells per case per Institution were analyzed in all cases. Totally 58,023 cells (about 2.67 million chromosomes) and in average 1,612 cells (about 74,000 chromosomes) per case were examined. Increase of the frequency of dicentrics and centric rings accompanied by fragments was detected in 18 cases. The estimated mean doses of them were: less than 5 mSv in 13 cases, 6-10 mSv in 3 cases, and 11-16 mSv in 2 cases.
ABSTRACTS

SS-II-3 Dose Estimation for the Overexposed Patients at the Criticality Accident in Tokai-mura

The doses for the overexposed patients were estimated by measurement of specific activity of $^{24}$Na in blood. The present method is almost based on the documents of IAEA and ORNL. The neutron energy spectrum obtained using ANISN code was assumed. The ICRP Publication 74 was cited for the doses in each organ per unit neutron fluence. The data on the environmental monitoring were used for the estimation of $\gamma$-ray to neutron dose ratio. Further investigation is in progress to evaluate more accurately the non-uniformity of doses at skin, depth dose distribution, $\gamma$-ray to neutron dose ratio, etc., where a Monte Carlo code of MCNP-4B is applied to the critical system accompanied with MIRD phantoms whose positions and postures are carefully modeled after those of the patients at the exposure.

SS-II-4 Exposure to high-dose neutron irradiation in the criticality accident at Tokaimura
Makoto AKASHI, Norikazu KURAOKA, Kenichi Nakagawa, Toshiyasu HIRAMAI; Division of Radiation Health, National Institute of Radiological Sciences

Since 1966, when the first nuclear reactor started operation in Japan, we fortunately have not had any nuclear accidents that required medical care for the people involved. However, a criticality accident occurred on September 30, 1999 at the uranium conversion facility in Tokaimura, Ibaraki, Japan. The criticality event occurred when a worker (B) was pouring a solution of enriched $^{252}$U into a precipitation tank directly and the other worker (A) was assisting him. At the accident, three workers including their supervisor (C) were severely exposed to neutron and $\gamma$-ray irradiation and develop acute radiation syndrome (ARS). Anorexia, nausea, vomiting, and diarrhea are typical prodromal symptoms observed in ARS. Upon the exposure, Worker A reported vomiting within minutes and loss of consciousness for 10-20 seconds. Worker A also had diarrhean hour after exposure. Worker B started to vomit an hour after the initial exposure. Their hematological data 2-3 hours after the accident showed markedly reduced numbers of lymphocytes. Because of detection of $\gamma$-ray from body surfaces of these workers by preliminary surveys and possibility of high-dose exposure, they were transferred to the National Institute of Radiological Sciences (NIRS). At the time of admission to NIRS, the body temperature of Worker A rose to 38.5 °C without any evidence of infection whereas these symptoms of nausea, vomiting, and diarrhea were not observed. An analysis by $\gamma$-spectrometry of vomitus from Worker A detected $^{24}$Na, suggesting exposure to neutron. Dose estimation for the three workers was performed by onset of prodromal symptoms, lymphocyte counting, chromosomal analysis, and $^{24}$Na activity. The average doses of the whole-body for Workers A, B, and C were estimated as 16-20 Gy equivalent to $\gamma$-ray (GyEq), 6-10 GyEq, and 4-5 GyEq, respectively. From these results, the severe bone marrow suppression was expected for these workers. Stem cell transplantation was performed for peripheral blood and cord blood for Workers A and B, respectively, and Worker C received cytokine therapy. Worker A developed severe radiation-burn involving over 50% of total body and gastrointestinal injury. Despite of all medical efforts, Worker A died of multiple organ failure 83 days after the accident. Worker B also died of multiple organ failure on 211 days.

SS-II-5 Chemical Analysis of the Uranium Solution for the Evaluation of Total Numbers of Fission in the JCO Criticality Accident
Kazuo WATANABE, Department of Environmental Sciences, Japan Atomic Energy Research Institute

The uranium solution from the JCO's uranium conversion facility was analyzed for the evaluation of total numbers of fission in the criticality accident. Two analytical groups in JAERI performed the chemical analyses in order to check the accuracy of the results: the concentration of fission products ($^{95}$Zr, $^{99}$Mo, $^{103}$Ru, $^{131}$I, $^{146}$Ba, etc.), uranium, boron, sodium and metal impurities in the sample. The analytical results obtained by the two groups were in agreement within an analytical error. The numbers of fission per one gram of uranium in the accident were evaluated to be $1.50 \pm 0.08) \times 10^{20}$. And the total numbers were determined to be $(2.49 \pm 0.14) \times 10^{18}$ using the total amount of uranium (16.6 kg) in the precipitation tank at the accident.

In addition, atom numbers of $^{239}$Np and $^{239}$Pu which had been produced by the neutron capture reaction of $^{238}$U in the solution were determined precisely after 265 days from the accident. It was found that the measured atom ratio of $^{239}$Np/$^{239}$Pu at termination of the criticality depends sensitively on history of the neutron capture reaction during the accident. Percentage of the numbers of the neutron capture reaction at the initial stage of the criticality during 25 min against the total events was determined to be 24 ± 6%.
ABSTRACTS

SS-II-6  Calculation of Leaked Neutron Spectrum and Induced Radioactivity by the Criticality Accident
Tetsuji IMANAKA; Research Reactor Inst., Kyoto Univ.

Neutrons played the main role in the environmental impact due to the JCO criticality accident. We began three-dimensional Monte Carlo calculation in order to reconstruct behavior of leaked neut in the environment. The strategy to promote the calculation was set up as the following steps: (1) Calculation of energy spectrum and angular dependency of leakage neutron. (2) Evaluation of the fission number by comparing calculated values of neutron-induced reactions with measurement at the precipitation and (3) Calculation of activities such as Mn54, Fe59, Co60 in soil and (4) samples around the conversion building (up to 20 m). (4) Neutron dose calculation around the JCO and comparison with measured values (up to 100 m). (5) Calculation of neutron dose and their spec resident areas around JCO (up to 300 m) and comparison with preliminary results obtained by 1-dimensional calculations. (6) Evaluation of neutron dose to persons who were in houses during accident, simulating shielding effects on the basis of forward-adjoint coupling technique.

We have already finished up to the third step till now. The total number of fission is evaluat 2.5 x 10^18 or 3.1 x 10^18 from Ni58(n,p)Co58 or Co59(n,γ)Co60 reaction, respectively. Our results are a good agreement with estimates by JAERI.

SS-II-7  Activation of Materials induced by the Neutrons from the JCO Criticality Accident
Kazuhisa KOMURA (Low Level Radioactivity Laboratory, Kanazawa University : Leader of the research group on the environmental impact of the criticality accident)

Enormous environmental materials were activated by the neutrons from the JCO criticality. More than 400 samples were collected by the research group not only in the JCO site but also in Tokai-mura and Naka-machi within 7 km range. To evaluate neutron influence and its energy information, (n,γ), (n,p) and (n,α) reaction products were measured by group members: Kanazawa Univ., Hiroshima Univ., Tokoku Univ., Ibaraki Univ., Niigata Univ., Aichi Medical School, Univ. of Tsukuba, Meteorological Res. Inst., National Inst. Radiological Sciences., National Inst. Environ. Studies.)

Neutron induced nuclides detected in plural samples are as follows;
- Soils in JCO site: 24Na (< 100 m), 56Sc, 56Fe, 60Co etc. (< 100 m), other(n,γ) products
- Gold items: 198Au (< 1400 m)
- Silverware: 110mAg (< 300 m)
- Cu/Ag coins: 65Zn, 63Cu, 60Co (< 300 m)
- Stainless steel: 54Cr (< 370 m) 56Fe, 59Co, 60Co
- Table salts: 32P (< 400 m)
- Fluorescent lamp: 132I, 137Cs (5) (< 200 m)

Among these most sensitive 198Au was detected up to about 1400 m from the JCO site. Relative production of 198Au as a function of distance was well reproduced by theoretical calculation based on DOT 3.5 model. Comparison with theoretical calculation was made also for 54Cr produced in stainless steel samples. Shielding effect was observed for the samples collected within 200 m for 198Au induced by fast neutrons.

SS-II-8  Doses to 350m zone-residents around Tokaimura JCO criticality accident site
J. Takada, S. Suga, K. Kitagawa, M. Ishikawa and M. Hoshi; RIRBM, Hiroshima Univ.

A criticality accident at the uranium conversion facilities in Tokaimura Japan on September 30, 1999 caused neutron exposure of residents. The distance between the nearest residence and uranium source was only about 100 m. Evacuation of people in 350 m zone was started after 5 h. There was a remarkable directional distribution on neutron beam which depends on complex internal and external structures of building surroundings critical uranium. The neutron flux changed 1.0-0.2 relatively in various direction. External effective doses on residents in 350 m-zone near the accidental factory were estimated taking account the directional dependence on radiation. The maximum and average doses for indoors of the western 350m-zone are estimated to be 12.1 and 2.2 mSv respectively. If the all of residents were indoor during the accident, 47% of those in 350 m-zone might have received external doses less than 1 mSv.