Nuclear accident in Tokai, Japan

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On 30 September 1999 two workers were pouring 18.8% enriched uranium into a precipitation tank at JCO Co. Ltd., a nuclear fuel processing company in Tokai, Japan for refining uranium fuel for the Joyo experimental fast breeder reactor. At 10:35 am on the day they heard strange sound like “bashi” with a blue flashlight and fled from the site with a supervisor who was next door. Three workers were heavily exposed to radiation and transferred to Mito Hospital (state-run hospital in Mito, Ibaraki Prefecture) by an ambulance at 12:07. The symptoms of those three patients were so severe that they were transferred to National Institute of Radiological Sciences (NIRS) in Chiba Prefecture by helicopter at 3:25 pm since NIRS is assigned to be the Third Stage Hospital in the case of a radiological emergency.

Response of government
The Science and Technology Agency received the first report on the accident from JCO at 11:15 am. Ibaraki Prefecture was then informed the accident at 11:33 am. A neutron monitor at the Naka branch of JAERI located 1.7 km away from the JCO showed a sharp peak at 10:35 am on 30 September. The gamma monitor at the same site showed a relatively small increase. The gamma dose rate at 13 points near the boundary of the JCO was started to measure at 11:36. A maximum gamma dose rate of 0.84 mSv h^-1 was measured just before the noon, where the normal value is around 0.2 mSv h^-1. Measurements of neutron doses were started at 7:09 pm around the facility with a delay of 8 hours from the measurement of gamma dose rates. The highest dose of 4.5 mSv h^-1 due to neutrons was observed.

The Tokai village authority issued an evacuation advisory at 3 pm to 200 people in 50 families living within a 350 meter radius of the plant and relocation at a public facility about 1.2 km away. The Ibaraki governor issued an advisory to the 313,000 residents living within a 10 km radius of the plant to stay indoors at 10:30 pm. They also recommended that people avoid using well water for the time being. In addition they instructed farmers to refrain from harvesting crops in the area until they were checked for radiation contamination.

A pair of workers was sent to the plant nine times to halt the chain reaction. At 6 am Friday, 1 October, the nuclear chain reaction was stopped by draining the cooling water in the water jacket around a precipitation tank by blowing the water with argon gas. The chain reaction lasted for roughly 20 hours. At 6:15 am the neutron monitor around the plant read zero. A boron solution was injected into the precipitation tank to ensure no more criticality. The highest dose for workers who risked exposure to radiation was 68 mSv.

The Chief Cabinet Secretary announced at 4:30 pm on the afternoon on 1 October that the government would allow residents living within a 10 km radius of the accident site to leave their homes and resume their normal lives because the area was deemed safe. However, the government left the evacuation order for the 350 m zone near the plant in effect. It was 6:30 pm on Saturday (2 October) that the government announced that its order cordonning off the area was lifted after intensive examination of radiation levels both inside and outside homes in the area. The authorities also conducted inspections of agricultural products both in the field and on supermarket shelves.

Victims
When the three victims were received at NIRS radiation safety staff surveyed the radiation level of the body as well as the inside of the ambulance. No contamination was found in the ambulance or on the attendants to the patients. However, the radiation levels around the patients were very high especially for the two highly exposed workers (Mr. O and Mr. S). Those two men were in so serious condition that medical treatment was urgently required. After the initial check they were moved to sterile isolation rooms.

A dose estimation team was established and measured patients’ blood as well as other items. Gamma spectrometry of clothes and vomited material and smear tests of their noses showed no trace of uranium-235 nor fission products except the daughter products of noble gas of Kr and Xe externally as well as internally. In contrast, a large amount of Na-24 was observed in addition to Br-80, Br-82 and K-42, which were derived from the neutron activation of the body elements.

The dose estimation based on the number of lymphocytes in their blood was treated as the first attempt of the dose estimation since the three men did not wear any dosimeters during their work. The doses were estimated to be more than 8 Sv for the two highly exposed victims (Mr. O and Mr. S) and 3 to 5 Sv for Mr. Y.

The measurements of Na-24 in their blood samples showed that their initial concentrations of Na-24 at the time of exposure were around 200, 100 and 30 Bq ml^-1, respectively. Initial gamma equivalent doses to the three patients were estimated to be 17, 10 and 3 GyEq, respectively using a RBE value of 1.7. Whole body counting of Mr. Y could also be carried out since he was in a relatively good condition.

On Monday, 4 October, another temporary dose estimation was completed by the chromosome aberration counting method and showed almost the same doses as derived from Na-24 activity measurements in
blood.

**Analysis of the accident**

Pouring 16.6 kg of 18.8% enriched uranium into the precipitation tank reached super criticality. Initial nuclear reaction lasted less than 100 millisecond and recorded a sharp peak on the gamma dose rate charts of several area monitors situated around 140 m away from the accident site. After the initial super criticality it is believed that the power of the nuclear reaction oscillated several times with an interval of about 10 seconds subsiding to a lower power production and reached to a relatively stable reaction, which lasted until next morning for 19 hours. There was no explosion or boiling of the solution. The period for initial 25 minutes till 11 am is called as the burst period and the period for other 19 hours called the plateau period. Total fission yield is estimated to be $2.5 \times 10^{18}$ by the radiochemical analysis of the solution sampled from the precipitation tank on 20 October. In addition to the solution analysis, a stainless steel net sample obtained outside the building, 1.8 m away from the precipitation tank, was measured by the gamma spectrometry and ICP-AES. The fission yield assigned for the burst period is 11% of the total.

The doses during the accident for about 20 hours were estimated based on the monitoring data of neutron and gamma with the help of computer simulation for energy spectrum. The revised dose estimation outside the facility was announced on 11 December 1999.

The accident is rated 4 on the international scale of 0 to 7 developed by the International Atomic Energy Agency and the Organization for Economic Cooperation and Development.