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Radioactive contamination around Jadugoda uranium mine in India

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1. Introduction - The uranium mine of India

India is the big nation where population exceeded 1 billion in May 2000. The land area is 3,290,000km^2. GNP is 340 dollars (1995) per person. The ratio of agriculture, forestry, and fishery worker is 61.6% (1995). A life expectancy is 60 years old of men and 61 years old of women (1992-1993). It has also severe caste system and there are still many poor people. And some people named “Untouchable” are set-aside even from the caste system. Although Gandhi called them "Hari Jean (Child of God)", they have the history of distress. Moreover, there are people with more distress history in this country. They are the aborigines (Native Indian). Many of them have lived in Bihar state of eastern India, especially in Jharkhand of Bihar. Jharkhand won the independence from Bihar in 2000 and 28% of its population is aborigines. It is a mineral rich state and the iron ore brought the first full-scale industrial city in India “Jamshedpur (Tatanagar)".

The nuclear test named "Smile of Buddha" was succeeded in 1974. Meanwhile, India has made efforts for the development of the nuclear power generation in order to utilize the rich thorium resources. Though it is 1957 that the nuclear reactor becomes criticality for the first time in Japan, the nuclear reactor becomes criticality in 1956 in India. It was the first nuclear reactor in Asia. Now 14 nuclear power plants are under operation and the total generating power is 2.72GW. Two reactors are boiling water reactor plants introduced from U.S.A. And two are CANDU reactors introduced from Canada, and then 10 of the remainder are the heavy water boiling reactors of the original development. In addition, 9 nuclear power plants are under construction including 2 Russian type pressurized water reactors. In India only Jharkhand has uranium mine, and it has contributed to both of the development of nuclear weapon and nuclear power plants. The map of the nuclear related facilities in India is shown in Figure 1, and the railroad map of Jharkhand is shown in Figure 2[1)].

Figure 3 is an artificial satellite photograph that shows the position of Jamshedpur (Tatanagar) and uranium mines around Jadugoda. The position of the central part of Jadugoda is east longitude 86-degree 20 minutes, and north latitude 22-degree 40 minutes. The distance from the Tatanagar station to Jadugoda is 24km in a straight line. The area around mines is mountainous land where the aborigines have lived. Aborigines were deprived of

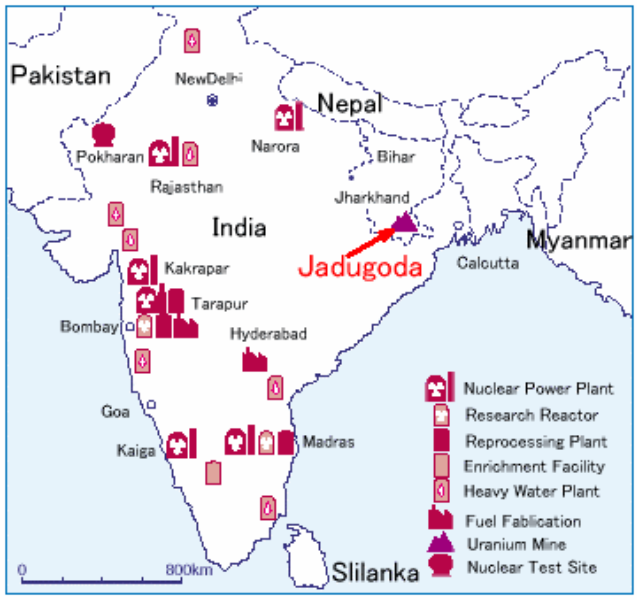


Figure 1 Nuclear colossus, India

their own land because uranium is discovered their land and they were polluted with radioactivity. They had to have a distress history for it. Uranium was discovered in many aborigines' lands like in the U.S.A. and Australia.

The population of Jharkhand is about 100 million and 1 million people live in its capital, Ranchi. There is West Bengal State on the east side and Orissa State is located on the south. Jharkhand state has the long slender area called "East Singhbhum" which lies between West Bengal and Orissa.

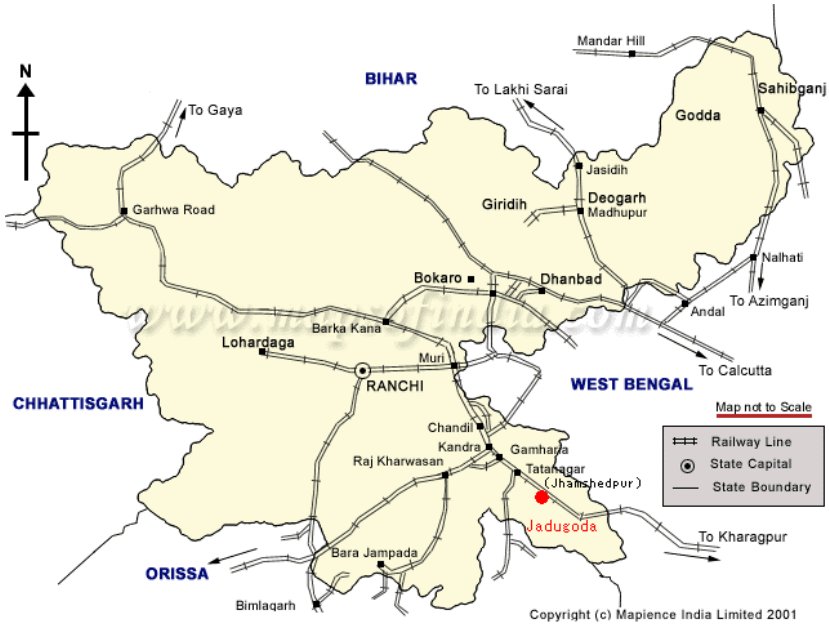


Figure 2 The Map of Jahrkhand

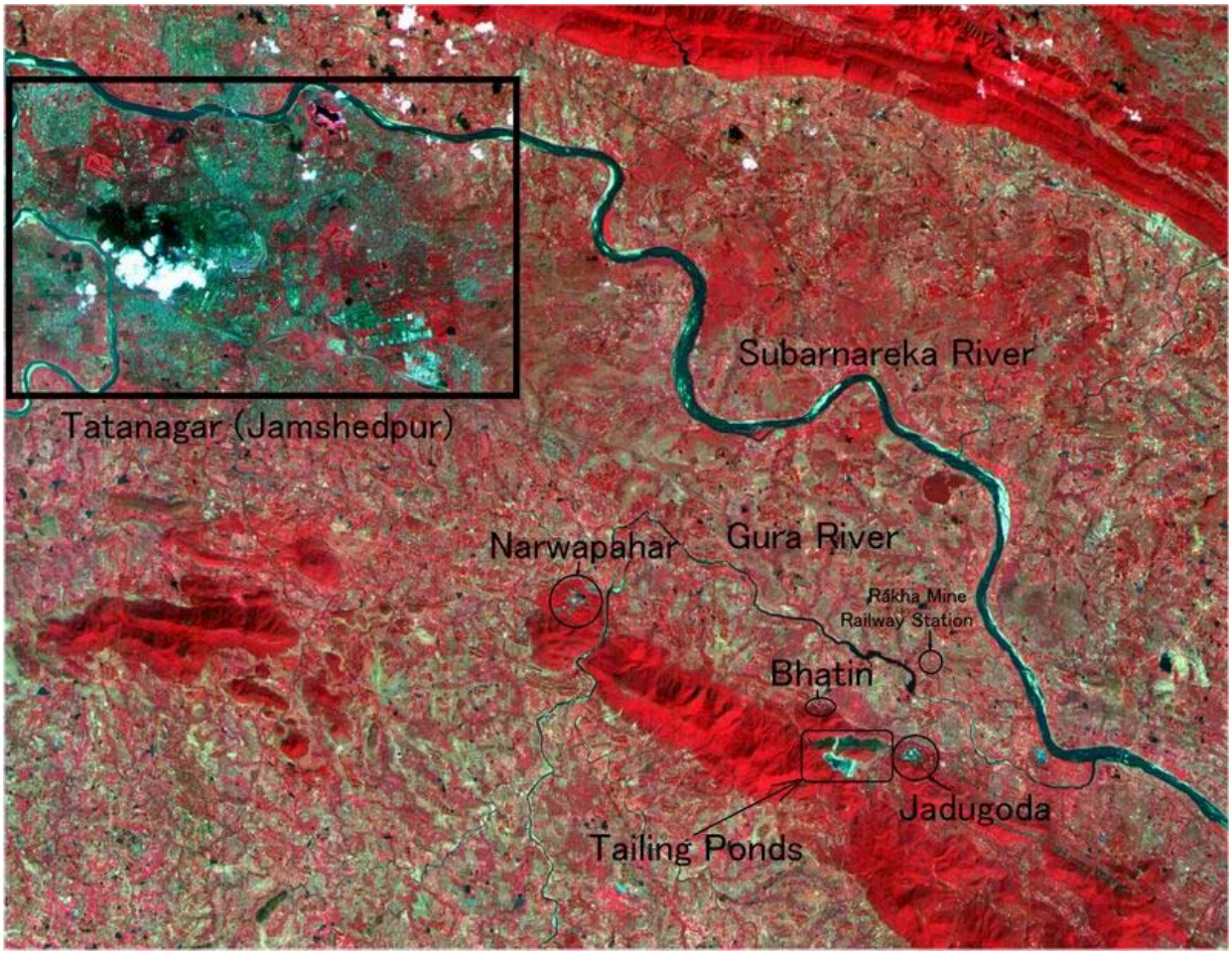


Figure 3 Satellite Photograph around Tatanagar and Jadugoda

Tatanagar and three uranium mines, Narwapahar, Bhatin and Jadugoda, are located in this area. These uranium mines are managed by UCIL (Uranium Corporation of India Limited), the government enterprise of India. The distance from Narwapahar to Jadugoda is only 10km. In Jadugoda, uranium ore from these three mines has been processed in a smelter. In addition, mill-tailings have been thrown away into three tailing ponds. The uranium got as a product is packed in the drum can and transported from the Rakha-mine railway station.

Though India has the rich thorium resources, it does not have the uranium almost. The grade of the uranium ore dug in these uranium mines is remarkably low. The average grade is about 0.06%. Ability of the smelter in Jadugoda is the ores of 1000 tons per day[2]. And the amount of uranium is only 600 kg per day, namely 200 ton per year. In the meantime, mill-tailings after uranium was removed reaches 300,000 ton per year. It has been thrown into tailing ponds by pipeline in liquid form. Besides, the mine-tailings also occur, and the quantity reaches 10 times of the mill-tailings. They are left in surroundings without any countermeasure.

The video movie “Buddha weeps in Jadugoda”[3] which received the grand prize in the global environment image festival 2000 taught me Jadugoda problem. The movies showed that there are 15 colonies within 5km around Jadugoda, about 30,000 people live, and much health disturbance on children of the nearby colony is being generated.

2. The investigation method

The main component of natural uranium is U-238, and its half-life is 4.5 billion years that are almost equal to the age of the earth. U-238 itself is a radioactive nuclide and the generated nuclides are also radioactive and repeat to decay one after another. It finally becomes a lead (Pb-206) after changing 14 kinds of radioactive nuclides. Those radionuclides were called as “daughters” or “progenies”. As the decay scheme is shown in figure 4, among the daughters some nuclides have unique danger such as radium and radon.

The uranium is a natural radionuclide and is not produced by human beings. So human beings have been exposed from uranium itself and its daughters. In addition, the exposure is added if the uranium is dug out from deep underground to the surface by the artificial action of the mining. Such exposure is called as TENR (Technologically Enhanced Natural Radiation and artificially raised natural radiation) and recently United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and International Commission on Radiation Protection (ICRP) would be taking up such exposure.

There are following three types exposure paths in the surroundings of the uranium mine.

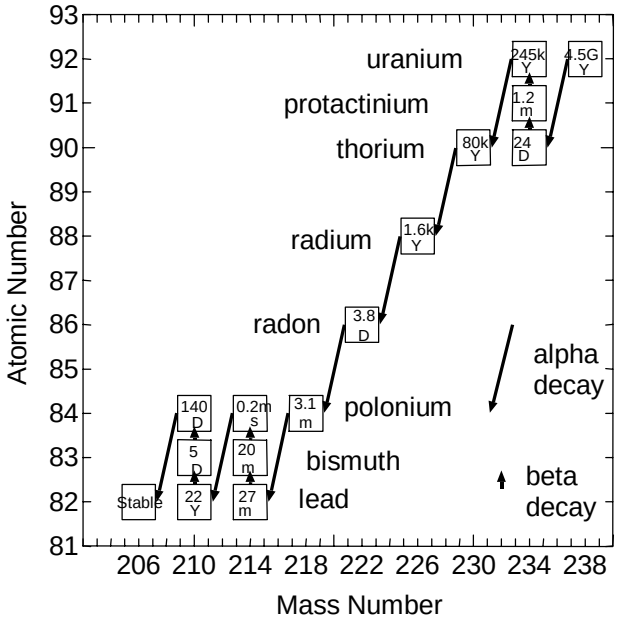


Figure 4 Decay scheme of uranium series.

1. The gamma-ray exposure by approaching tailing ponds or mine-tailings.
2. The internal exposure by taking water or food contaminated by uranium and the daughters.
3. The internal exposure by inhaling radon in the air.

I carried out following three type investigations in order to consider such exposure.

A. Measurement of gamma radiation dose

TLDs (Thermo Luminescence Dosimeter: Matsushita Electric Co.Ltd., type UD-200S and UD-110S) were placed in the field, and they were recovered after 3 months. A cumulative dose was measured by the TLD Reader (Matsushita Electric Co. Ltd., UD-5120PGL) of KURRI (Research Reactor Institute, Kyoto University). The exposure dose under transportation of TLDs was corrected using the dose data of control samples and dose rate data in the aircraft anticipated generally. Beside, the direct measurement in the field by the survey-meter (Horiba Ltd., PA-100, ORIENT Co.Ltd., PSD06021 and Belarusian PDM-2) was also carried out. Both measurement results showed the approximately good coincidence.

The location of the villages around Jadugoda is shown in Figure 5. The measurement result by the survey meter and TLDs are shown in Table 1 and Figure 6. Although not shown in this table, measurements by survey meters have been performed at many places in villages. The dose rates are in 0.1-0.2 μSv/h anywhere except Dungridih, and this is the background value of the air-gamma dose in this area. The measured value by PDM-2 gives a little higher value than real. Therefore, its value shown in Table 1 approaches the usual background value in Japan etc., 0.05μSv/h. However the report[4] of Green Peace indicated that the background of this area to be 0.08-0.14 μSv/h, so the background of this area is considered to be little higher than that of the usual area in the world. However, even if they are high, they are double or three times at most. The dose limit for the public from the artificial causes is determined as 1 mSv/y (0.11 μSv/h). In Jadugoda, there are places where the external gamma dose due to only natural radiation exceeds this limit. This, however, occurs in the natural course, so we cannot avoid it. On the other hand, the artificial source of exposure exists in Jadugoda and it can be avoidable. The most remarkable cause of exposure lies in tailing ponds where

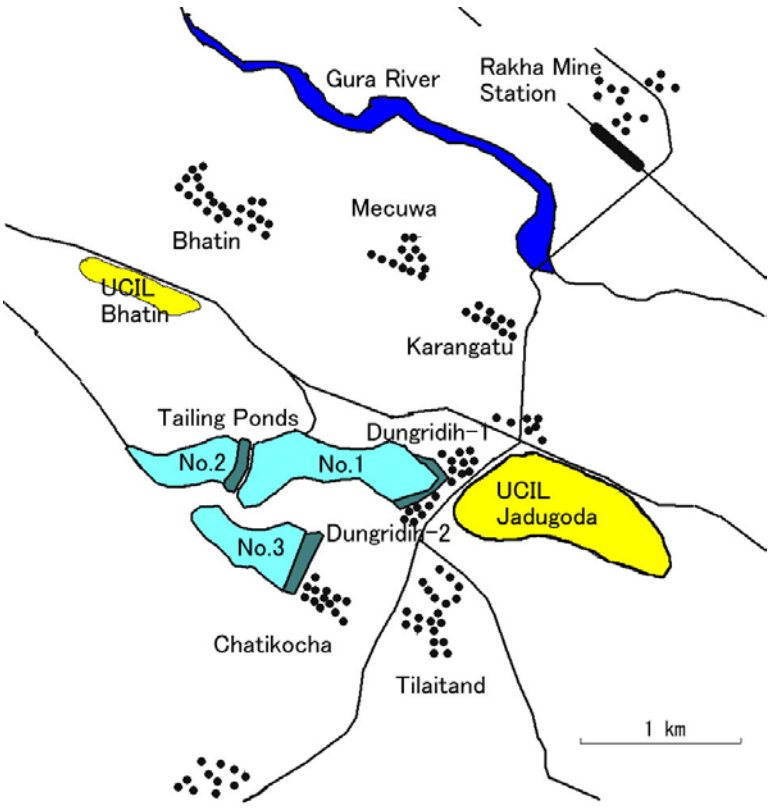


Figure 5 Village Map around Jadugoda

the air-gamma dose exceeds 10mSv/y (1.1μSv/h). UCIL enclosed this area by the barbed wire. But this area had been farmland or village of residents and even now it is the place of their everyday life. When I entered into a tailing pond and collected the sample, two women were crossing a tailing pond putting firewood on their head.

Table 1 The result of the measurement on Air-gamma dose rate

	Point (remarks)		Survey Meter			TLD	
			μ Sv/h			μ Sv/h	
			Dec,2001 ,PDM-2		Apr.2003, PM-100	2000/9/10-2000/12/7	2003/4/13-2003/8/15
			1m	Surface	1m	1m	
	Tailing Ponds						
a	No.1		0.84	-			
b	No.1		0.79	0.9	0.8		
c	Boundary of No.1		0.71	0.83	0.4	0.47	
d	No.2		1.1	1.2	0.7	0.91	
	path to No.2				0.02-0.04		
e	No.3		0.73	0.83			
	Village						
f	Dungridih 1	Entrance	0.13	-	0.08-0.09		
g		Center	0.17	-		0.24	
h		Fence	0.34	-			
i		Former mine tailing pond	0.39	-			
j	Dungridih 2	Entrance	0.36	-	0.06-0.08		
k		Center (beside a dam)	0.3	-			
l		Back	0.16	-		0.11	
m	Chatikocha	Back (beside a dam)	0.2	-	0.02-0.03	0.14	
n		Sideway	0.13	-		0.1	0.071
o	Tilaitand	Garden (Mr. Biluri's house)	0.12	-	0.04-0.06		
p		Field (near a school)	0.13	-			
q		Backyard (Mr. Biluri's house)	0.13	-			
r	Bhatin	Field	0.14	-	0.04-0.05	0.11	
s		Garden (once used mine tailings)	0.16	0.21			
t		Garden	0.12	0.12			0.086
u		Pond	0.13	-			
	Mecuwa				0.05-0.06		0.088
	Kuldiha				0.05-0.06		
	Road Side						
v	Bhatin		0.22	-			
w	Micuwa (mine tailings)		-	0.7			
	Near cupper mine		0.2	0.22			
x	Entrance to Tilaitand		0.22	-			
y	Main Crossing Road near Shidhu Kanu Chowk		-	-		0.14	0.15
z	Rakha Mine Station		0.21	-			
	Control						
	Dhirol(another Tilaitand)						0.16
	Scheduled site of Shelter		0.14	0.16	0.04-0.06		0.11
	Ranchi (garden of Mr.Shriprakash's house)		0.25	0.3		0.23	
	KURRI（Kumatori, Japan）		0.08	0.04-0.05	0.03-0.04	0.046	0.047

B. Radioactive concentration in soil

At first residents collected soil samples in autumn of 2000. Next, I collected samples at the end of 2001. The radioactive nuclide was measured by gamma-ray spectrometry using the High-Purity Germanium semiconductor detector (EG&G, reverse electrode type, relative efficiency: 34%, half-width 1.8keV) in KURRI. Total 42 samples were measured and the result of these measurements is reported.

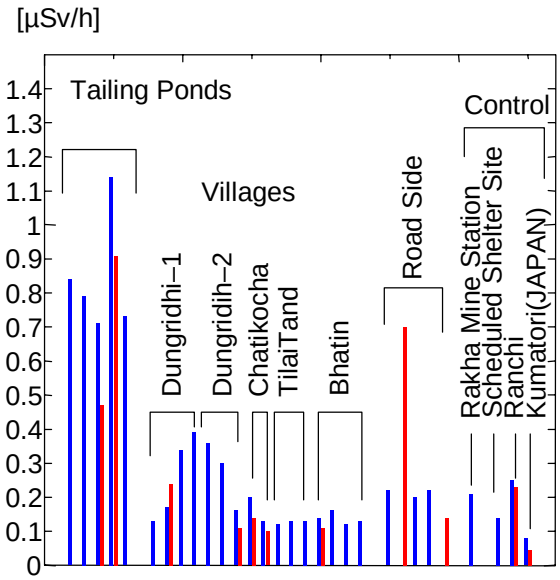


Figure 6 Air–Gamma Dose around Jadugoda and controls

a. Contamination unrelated to uranium mine

At first, the concentration of radioactive nuclides unrelated to the uranium mine are shown in Table 2 and Figure 7. The concentrations of typical radioactive material in the crust are almost same in Jadugoda and in KURRI. However, in Ranchi the concentration of K-40 and thorium is remarkably high. The reason that the sample of Ranchi contains much K-40 and thorium will be based on the character of the local crust.

The U.S.A., U.S.S.R. and few other countries conducted the atmospheric nuclear test more than 500 times in the 1960s. Many fission products polluted all over the world. However, since many of nuclear test sites were located in the Temperate Zone of the Northern Hemisphere, this area has been received especially high contamination. Japan belongs to this area and India does not. Therefore, it was expected that the concentration of Cs-137, which is main fission products, in Japan is higher than that in India. The measurement result here has supported this fact. That is, Cs-137 concentration in the soil in KURRI is several times higher than that in Jadugoda. However, Cs-137 concentration of the sample collected in the No.1 tailing pond is several times higher than that in KURRI. Its value is 10 or more times higher than that of other samples in Jadugoda. It is reported that the radioactive waste from various parts of India has been carried and abandoned into the tailing pond of Jadugoda. Unusual contamination of Cs-137 in No.1 tailing pond is considered to show this fact.

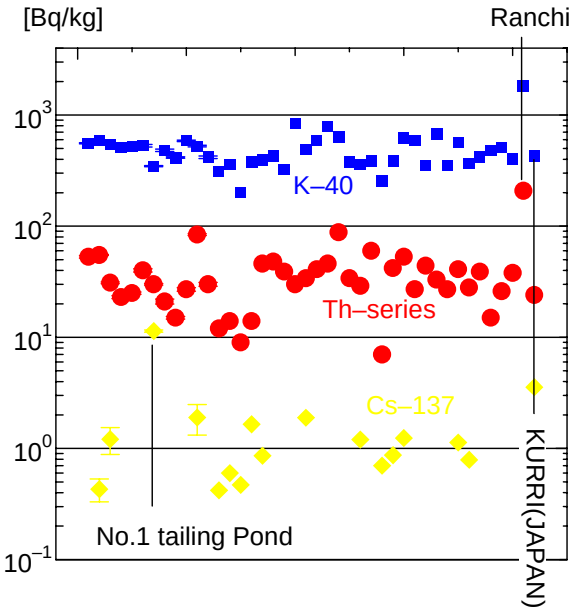


Figure 7 Concentration of unrelated Nuclides with Uranium

Table 2 Concentration of unrelated Nuclides with Uranium

		Th-series		K-40		Cs-137	
		Bq/kg	SD	Bq/kg	SD	Bq/kg	SD
	Rakha Station						
2	Railway station Rakha mines	53	2.3	550	1.2	ND	
106	Rakha Mine Station	55	1.1	600	0.6	0.43	22
	Around tailing ponds						
3	Near tailing pond	31	1.9	540	0.8	1.2	27
4	Near tailing pond	23	2.8	510	1.2	ND	
5	Near tailing pond	25	2.4	520	1.1	ND	
115	Tailing Pond No.1 entrance	40	3.3	530	2.6	ND	
6	Tailing pond no. 1	30	1.6	350	1.1	11	2.2
116	Tailing Pond No.1	21	5.1	480	2.6	ND	
8	Tailing pond no. 2	15	2.8	420	1.2	ND	
117	Tailing Pond No.2	27	3.5	590	1.6	ND	
7	Tailing pond no. 3	84	1.8	530	1.7	1.9	30
118	Tailing Pond No.3	30	3.9	420	2.6	ND	
	Villages						
9	Chatikocha near ratan's house	12	1.4	310	0.6	0.42	12
10	Chatikocha near ishwar's house	14	1.7	360	0.7	0.60	12
107	Chatikocha, front of Tailing Dam	9	2.3	200	0.9	0.47	13
108	Chatikocha, field in the village	14	2.1	380	1.7	1.7	13
11	Mechuwa (Dungridih) near prabhat baske's	46	0.9	400	0.9	0.86	17
109	Dungridih, back in the village	48	1.1	430	0.9	ND	
Un04	Dungridih, entrance to the village	39	1.1	330	1.0	ND	
Un01	Dungridih, old tailing pond	30	2.5	850	1.1	ND	
12	Mechuwa (tuare Dungridih) near futani tati's	34	1.1	490	0.6	1.9	5.9
13	Mechuwa (tuare Dungridih) near tati's house	41	1.0	590	0.5	ND	
112	Dungridih 2, back in the Village	46	1.4	790	0.7	ND	
113	Dungridih 2, entrance	88	1.4	630	1.1	ND	
un03	Dungridih 2, most back	34	1.6	380	1.1	ND	
14	Tilaitand near pulin banra's house	29	1.0	360	0.6	1.2	7.2
20	Tilaitand near tapash's house	60	0.6	390	0.7	ND	
un02	Tilaitand, school	7	2.2	260	0.8	0.70	9.1
15a	Mecuwa near mirja shoren's house	42	0.9	380	0.8	0.87	11
16	Bhatin near gundi hembrom's house	53	0.7	620	0.5	1.2	8.2
	Road or River Side						
104	Mecuwa Road Side	27	2.4	590	1.0	ND	
105	Mecuwa Road Side (Mine tailing)	44	2.1	350	2.1	ND	
17	Near high school Jadugoda	33	0.7	680	0.4	ND	
18	The main crossing road near jagdish bastra-	27	1.4	350	0.9	ND	
19	The main crossing road near shidhu kanu	41	1.1	570	0.5	1.1	11
21	Gura river near lord shiva temple	28	1.5	370	1.1	0.79	24
22	Gura river near the big dam	39	0.8	420	1.1	ND	
23	Near the nala along the road side	15	4.6	480	1.3	ND	
un05	Tailing Pond No.1 outlet stream at Dungridih 2	26	1.6	510	0.7	ND	
120	UCIL Outlet	38	2.3	410	2.0	ND	
	Control						
24	Ranchi	210	0.4	1800	0.4	ND	
25	KURRI, JAPAN	24	1.0	430	0.6	3.60	2.6

b. Contamination related to uranium mine

Of course, the index of the contamination related to uranium mine is uranium. And it can be proved physically that the radioactive intensities of uranium and its daughters become the same if all these nuclides remain in the same place. Such a state is called "radioactive equilibrium". For example, when uranium exists in a deep underground, such a state establishes. Radium tends to solve into water compared with uranium, and radon is the gaseous nuclide that belongs to the rare gas. Therefore, when a uranium ore is taken out to surface of the earth, they move from the place easily. Moreover, if uranium is smelted, it will move to a product and will decrease in tailings.

Then, in analysis of the uranium in soil, following three kinds of radioactivity was determined. 1: From uranium-238 to thorium-230. 2: Radium-226. 3: The daughter nuclide below Polonium-218. The result is shown in Table 3 and Figure 8. The value in KURRI was shown in the right end, and it is a value without contamination of uranium mine. There are samples in the village, road and riverside of the Jadugoda that show the almost same value as the sample of KURRI. This shows that in Jadugoda there is the place that has not contaminated by a uranium mine. However, also in the same village, the same road and the riversides, some soil samples have extraordinarily high uranium concentration. Moreover, uranium concentration in the tailing pond is remarkably high. In almost all samples, the concentration of uranium, radium and daughter nuclides is same and does not move greatly from the state of “radioactive equilibrium".

The only exception is the sample collected at the Rakha mine station; in this sample only uranium existed by remarkably high concentration.

In order to see this point in detail, figure 9 shows only the measurement result of tailing ponds and Rakha Mine Station. While in the sample around tailing ponds the concentration of uranium, radium and daughter nuclides show almost same value, only in Rakha Mine Station sample only uranium concentration is extremely high compared with radium and other daughter nuclides. This shows that the uranium obtained by smelting fell around the station and extended contamination. In addition, the fact that there is a big difference in uranium concentration in two samples collected in the station shows that the actual shipment work has been done in the restricted area.

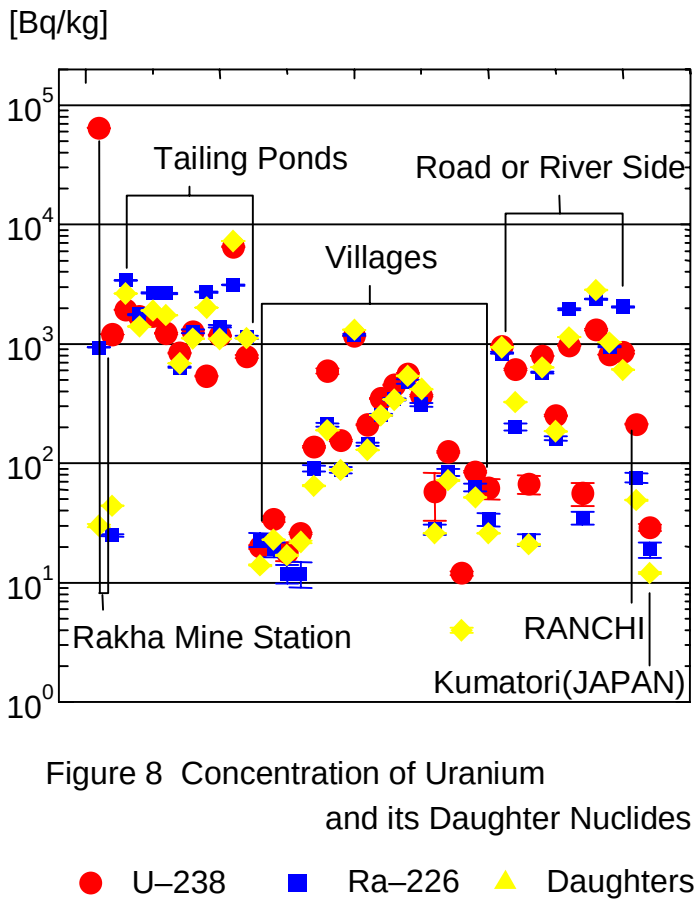


Figure 8 Concentration of Uranium and its Daughter Nuclides

Table 3 Contamination related to uranium mine

		U-series		Ra-226		Daughter	
		Bq/kg	SD	Bq/kg	SD	Bq/kg	SD
	Rakha Station						
2	Railway station Rakha mines	6400	0.1	940	0.2	30	3.0
106	Rakha Mine Station	1200	0.5	25	2.4	44	0.7
	Around tailing ponds						
3	Near tailing pond	1900	0.7	3400	0.5	2600	0.1
4	Near tailing pond	1700	0.9	1800	1.0	1400	0.2
5	Near tailing pond	1710	1.0	2700	0.8	1900	0.1
115	Tailing Pond No.1 entrance	1200	1.3	2600	1.3	1700	0.2
6	Tailing pond no. 1	840	1.0	640	1.4	690	0.2
116	Tailing Pond No.1	1300	3.0	1300	3.7	1100	0.4
8	Tailing pond no. 2	540	1.7	2700	1.0	2000	0.1
117	Tailing Pond No.2	1200	1.4	1400	2.3	1100	0.3
7	Tailing pond no. 3	6500	0.7	3100	0.7	7300	0.1
118	Tailing Pond No.3	790	3.0	1100	3.1	1100	0.4
	Villages						
9	Chatikocha near ratan's house	20	4.1	23	13.0	14	1.1
10	Chatikocha near ishwar's house	34	5.5	19	14.0	23	1.0
107	Chatikocha, front of Tailing Dam	18	16.0	12	19.0	17	1.1
108	Chatikocha, field in the village	26	2.2	12	25.0	22	2.2
11	Mechuwa (Dungridih) near prabhat baske's house	140	1.9	91	5.9	65	0.7
109	Dungridih, back in the village	590	5.1	210	3.6	190	0.4
un04	Dungridih, entrance to the village	160	2.1	88	5.7	88	0.5
un01	Dungridih, old tailing pond	1200	1.3	1200	1.8	1300	0.2
12	Mechuwa (tuare Dungridih) near futani tati's house	210	1.4	150	2.9	130	0.4
13	Mechuwa (tuare Dungridih) near tati's house	350	1.1	260	2.0	250	0.3
112	Dungridih 2, back in the Village	450	1.2	340	2.4	340	0.3
113	Dungridih 2, entrance	560	2.3	480	4.0	540	0.4
un03	Dungridih 2, most back	370	1.8	310	3.3	420	0.3
14	Tilaitand near puling banra's house	58	43.0	28	9.6	26	0.8
20	Tilaitand near tapash's house	130	2.0	84	6.5	72	0.5
un02	Tilaitand, school	12	4.6			4	3.6
15a	Mecuwa near mirja shoren's house	85	1.9	63	7.3	52	0.7
16	Bhatin near gundi hembrom's house	62	19.4	34	12.0	26	0.9
	Road or River Side						
104	Mecuwa Road Side	960	1.1	840	1.7	940	0.2
105	Mecuwa Road Side (Mine tailing)	610	2.1	200	6.9	330	0.6
17	near high school Jadugoda	67	18.0	23	11.0	21	0.9
18	the main crossing road near jagdish bastralaya	790	0.7	580	1.4	640	0.2
19	the main crossing road near shidhu kanu chowk	250	1.3	160	3.8	190	0.3
21	Guar river near lord Shiva temple	970	0.9	2000	1.8	1100	0.1
22	Gura river near the big dam	56	22.0	35	12.0	21	1.1
23	Near the nala along the road side	1300	1.7	2400	0.9	2820	0.1
un05	Tailing Pond No.1 outlet stream at Dungridih 2	810	0.9	950	1.3	1000	0.1
120	UCIL Outlet	860	3.1	2000	1.2	61	0.3
	Control						
24	Ranchi	210	1.2	76	9.2	49	0.8
25	KURRI, JAPAN	29	6.8	19	15.0	12	1.5

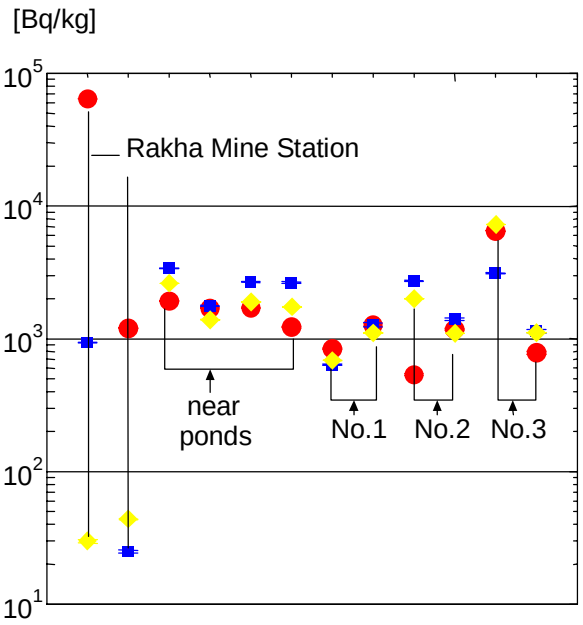


Figure 9 Concentration of Uranium and its Daughter Nuclides (in and around tailing ponds)

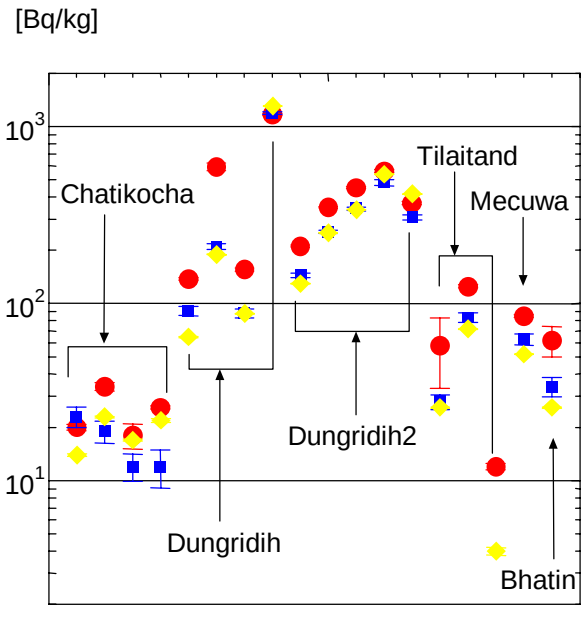


Figure 10 Concentration of Uranium and its Daughter Nuclides (in and around villages)

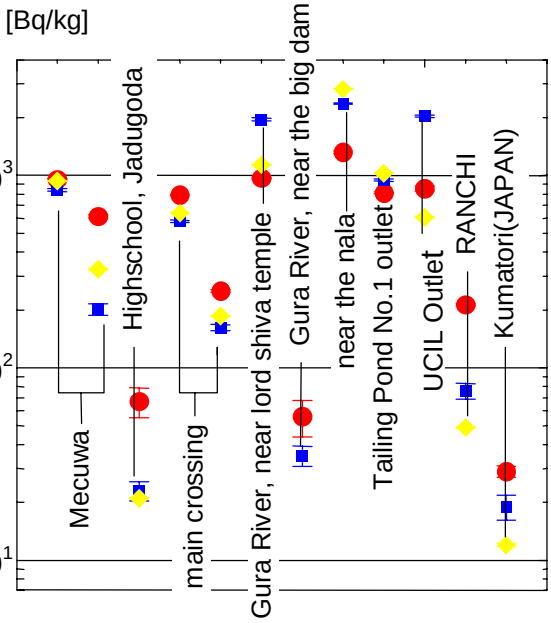


Figure 11 Concentration of Uranium and its Daughter Nuclides (Road or River Side and Controls)

U–238 Ra–226 Daughters

Figure 10 shows only the data related to villages. In the villages of the Jadugoda, the uranium concentration in Dungridih-1 and Dungridih-2 is high and it is clear that these villages were contaminated by tailings. In addition, there are big differences in the uranium concentration in other villages. This fact shows that the tailing is carried into the village, which has not been contaminated originally, as construction materials of houses or roads. This will become still clearer if we check about the sample along a road. Figure 11 shows the data of the soil of the road, the riverside and the brook that flows from a tailing pond and UCIL. The value of samples of Ranchi and KURRI (Japan) is also shown in this figure as control. It turns out that uranium concentration is remarkably changed in the sample of the same road or the river. This shows that whether tailings were used or not for the construction materials of the road and the bank of river has great influence. Moreover, the water that has flowed out of a tailing pond or UCIL is polluted with uranium, so a river is also contaminated.

C. Radon concentration in air

The method of radon measurement that I am using consists of the following processes. First, activated charcoal (Tsurumi-coal Co.Ltd., TC-2GS) sample is arranged in the measurement point. Second, activated charcoal adsorbs radon while it is being left for about one day. Third, samples are collected, and radioactivity is measured by gamma ray spectrometry. We have to perform the measurement in KURRI with special measurement apparatus. Radon is the radioactivity of the comparatively short half-life 3.8 days. If samples were mailed, Radon would be lost before measurement. Therefore, I went to Jadugoda by myself and returned to KURRI immediately after the collection of radon.

In the first measurement done on December 2001, three samples were preliminary analyzed. The result showed that the radon concentration at the tailing pond is high as was expected and moreover extremely high at the ventilation outlet of Bhatin mine. The cool air from deep underground was thrown out there, so residents gathered there in hot summer[5]. In the second measurement, 14 samples were analyzed. Both first and second measurement results were shown in Table 4, and they indicated as followings.

Table 4 Radon Concentration in Air.

Place	Radon Concentration [Bq/m^3]
First Measurements： Measurements in December, 2001	
Tailing Pond No.1, Inner	260
Village, Tilaitand	45
Bhatin Gallery	2400
Second Measurements: Measurements in April, 2003	
Tailing Ponds	
No.1 entrance	65
No.1 Inner	59
No.2 entrance	20
No.2 Inner	80
No.2 path	15
Villages	
Dungridih 1	26
Dungridih 2	24
Chatikocha, Dam Side	8
Tilaitand	23
Bhatin, entrance	23
Bhatin, inner	16
Micuwa, entrance	13
Micuwa, Inner	12
Rakha Mine Station	9
Normal Environment	3～20

① Since the radon concentration of the usual outdoor environment is about 10 Bq/m^3, the radon concentration in the village of the Jadugoda has been somewhat high.

② The value in tailing ponds is dozens times, and it seems that the contamination of radon has spread from the tailing pond into villages.

③ Moreover, the value in the exhaust gallery of a Bhatin mine is further 10 times.

④ But except tailing ponds and exhaust outlet, the radon concentration in Jadugoda area is not too high. Exposure of the laborers who work in an underground tunnel is anxious. Especially it is said that the digging tunnel that was a depth of about 500 to 600m at the beginning has now become no less than 1000m depths under-

ground. The biggest healthy problem that the residentsof Jadugoda are faced is exposure of mine laborers.

3. Conclusion --- Serious Problem

A. Contamination exists

Contamination surely exists around Jadugoda uranium mine. If uranium is exploited and is left on the surface of the earth, there is no reason in which the pollution is not generated. Moreover, if unmanageable tailings are positively used for the construction materials of the building or the road, contamination will be expanded further. According to the request of JOAR (Jharkhandi Organization Against Radiation), the Environment Committee of the Bihar Legislative Council was installed. The committee issued the last report in December 1998 after investigating the circumference over two years. The report indicated, "There should be no village up to at least 5km., from the dumping ground area." However, according to my investigation, contamination centering on tailing ponds seems to have not spread yet broadly. Since two villages, Dungridih-1 and Dungridih-2, are in contact with the tailing pond, soil is polluted and the air-gamma dose is also high. On the other hand, in the villages including Tilaitand those are not directly in contact with tailing ponds the air-gamma dose is not high. In addition, the soils of these villages were not contaminated by tailings, either.

The result of this investigation is summarized below.

1. **The contamination from the uranium mine has spread in Jadugoda.**
2. **The amount of air-gamma dose exceeds 1 mSv/y in the villages, and reaches 10 mSv/y around the tailing ponds**.
3. **The circumference of tailing ponds is polluted with uranium. The strength of the pollution in the tailing ponds is 10 to 100 times higher than the place without contamination.**

   Since the uranium content of uranium mine around Jadugoda is low, the air-gamma dose rate and uranium concentration of a tailing ponds are not extremely high. As long as tailing is abandoned, it is reasonable that the air-gamma dose rate and the uranium concentration in soil in tailings ponds are high. In addition, the radon concentration in the air is also high. As shown in Table 1, the dose rate reaches 1 μ Sv/h and tailing ponds should be managed as a controlled area of the radiation. However, when I entered into the inside of a tailing pond in order to collect the soil samples for radioactivity measurement, two women were crossing a tailing pond putting firewood on their heads. For a long time, residents have been nestling up to nature. Tailing pond were built where the place of a daily life of the residents. As the Environmental Committee of the Bihar Legislative Council has already pointed out, the tailing pond is the place of an every-day life of residents. Even now, they cannot but enter into tailing ponds in order to live. Residents receive excessive exposure by the gamma ray from the ground only by entering into these tailing ponds, and they receive further exposure by inhaling the radon that escapes from the ground and by making tailings adhere to the body. Tailing ponds are dangerous places and the measures that prohibit the inhabitant to enter into the tailing ponds must be taken. Now, the barbed wire stretched around tailing ponds is cut everywhere. At first, it is necessary to stretch barbed wire again. An essentially required thing, however, is telling residents about the danger of tailing

ponds. In addition, it is necessary to make the conditions that the inhabitant would also live on not entering tailing ponds.

4. **No.1 tailing pond has contamination of cesium. This fact shows that radioactivity was brought from another polluted source that was not uranium mine.**

5. **Especially Dungridih that is in contact with the tailing pond has high contamination. However, other villages have not contaminated seriously yet.**

   The villages of Dungridih and Chatikocha are directly under tailing dams. In order to make tailing ponds, land was taken and residents settled there reluctantly. The water from tailing ponds flows there in the rainy season. And tailings that became a fine particle carried there by the wind in the dry season. Especially the uranium concentration in soil in Dungridih is high (cf. Table 1) and therefore the rate of air-gamma dose rate is also high (cf. Table 2). Residents have better be emigrated another villages if tailings will be throw away into tailing ponds.

6. **Radon emanated from tailing ponds etc spreads contamination.**

   As already mentioned, residents had gathered at the exhaust outlet in the summer. I visited there on December 2001. Although there was no roof in order to blow out the air, there was enclosed by concrete building. I jumped into inside from the upside opening in order to install the activated carbon sample for radon collections. Cold damp air was violently blowing off there. Although it was too late, installation of a concrete building was the needful measure. However, from the tailing ponds, radon is spreading now and its behaviour should be monitored.

7. **Mine-tailings used for construction material spreads pollution**

   There is a shade of uranium contamination in a same village, as high contamination has been measured at Tilaitand or other village. This cause is because tailings were used for the building materials. There are places where uranium concentration is high at the road or the riverside, and it is thought that tailings are used for construction material too. Residents testified followings. When they told UCIL that they wanted construction materials, UCIL carried mine-tailings by dump trucks. It must be immediately stopped to bring tailings into villages and to use it for construction materials.

8. **Product uranium is dealt with carelessly and has fallen in environment**

   While it is important to prevent the pollution of mill and mine-tailings, product uranium has also been dealt with carelessly. At the Rakha Mine station, the soil is severely polluted by only uranium. Its concentration is remarkably high. This shows that the product uranium obtained by smelting fell and extended contamination**.** Table 5 shows the measurement result of two samples collected at Rakha Mine station. The concentration of Ra-226 and other daughter nuclides are extremely low compared with the concentration of uranium. This fact

indicates that the condition of the radioactive equilibrium was not established. The product uranium (Yellow cake) gotten through the process of digging and milling is put in a drum and conveyed from Rakha Mine station. However, the hole has opened a part of drum can by the corrosion, the yellow cake spills from the inside and scatters to the circumference. While such an act makes uranium wasted, it also becomes the cause of contaminating residents.

Table 5 Concentration of U-Series Nuclides in the Samples of Rakha Mine Station.

Nuclides	Bq/kg	Bq/kg
U-238	64000	1200
Ra-226	940	25
Daughters	30	44

9. The concentration of Natural Radionuclides is high in Ranchi

As is shown in Table 2, in Ranchi, the capital of Jharkhand state, the concentration of natural radionuclides such as K-40 and Thorium in the soil is high. In addition, Table 3 shows that not only K-40 and thorium but also uranium concentration is high in Ranchi. It, however, is generated from the natural cause and therefore it cannot be avoided.

B. About the construction of Shelter

Due to the native abnormalities are occurring frequently in children in Jadugoda, the support organization "the fund of Buddha's sorrow" born in Japan is constructing a "shelter" in the place about 20km away from Jadugoda, and is planning to evacuate Jadugoda children into it. As the amount of air-gamma dose in that place was already shown in Table 1, it does not change with the ordinary village in Jadugoda except Dungridih-1 and Dungridih-2. Therefore, exposure cannot be reduced even if the children of villages other than Dungridih were accommodated in the shelter. Jadugoda is not the society where everyone can use cars like of Japan. Then, is it good to accommodate children in the shelter far distant from the place of their life? Ranchi, Jharkhand state's capital, has the high concentration of the natural radionuclides with the origin in earth crust and the amount of air-gamma dose is high as shown in Table 1. Therefore, if the shelter for the children is built in Ranchi and children are accommodated there, exposure of children will increase rather.

However, efforts of the aborigines to construct the shelter are already progressing with involving in much villages and residents, and become the big power for building aborigines' solidarity.

C. Structure of discrimination

Jadugoda was an aborigines' land originally. However, uranium was exploited and residents were deprived of land. The residents, who were deprived of the farmland or the village itself, live in the village of Dungridih or Chatikocha. When I visited Dungridih, one resident came and told us something by the angry face. I heard later that he had said, "I understand that this village is dangerous. However, where we can live really?"

D. We should avoid the exposure without a reason.

Even if the radiation dose may be very low, it accompanies risk. However, since there is the natural radioactivity on the earth and radiation such as a cosmic ray, we cannot escape the exposure completely. There is also an area

where the content of the uranium or thorium in soil are high, and peoples are received exposure of 10 or more times in such a place compared with other areas. There is no other way but to accept. Ranchi, the capital of Jharkhand, is one of such the places.

On the other hand, man's act may also induce exposure. One example is going on in Jadugoda. Moreover, the aborigines who are prevented even from caste are having the exposure forced.

The aborigines of Jadugoda were destroyed their life by depriving of their land. They were destroyed their health by becoming the laborers of a huge government enterprise. Moreover, radioactivity is thrown away into the place of their every-day life and they have been exposed further.

E. The abolition of the nuclear development

The energy density of nuclear fission is high. Therefore, the quantity of the fuel carried into nuclear power plant is less than that of the fossil power plant. The nuclear promoter has asserted that it is the advantage in utilizing the nuclear energy. As shown in Figure 12, however, the quantity of mine- and mill tailings is tremendous. The uranium which failed to separate in the smelting, the Th-230 with the half-life 80000 year and all of the daughter nuclides after Th-230 are contained in mill-tailings. Because the uranium concentration of mine-tailings is lower than that of uranium ore, it is abandoned. Nevertheless, it surely contains the uranium and all of its daughter nuclides.

It is the most important not to leave them in the environment. But these radioactive wastes has been left in the environment in anywhere around

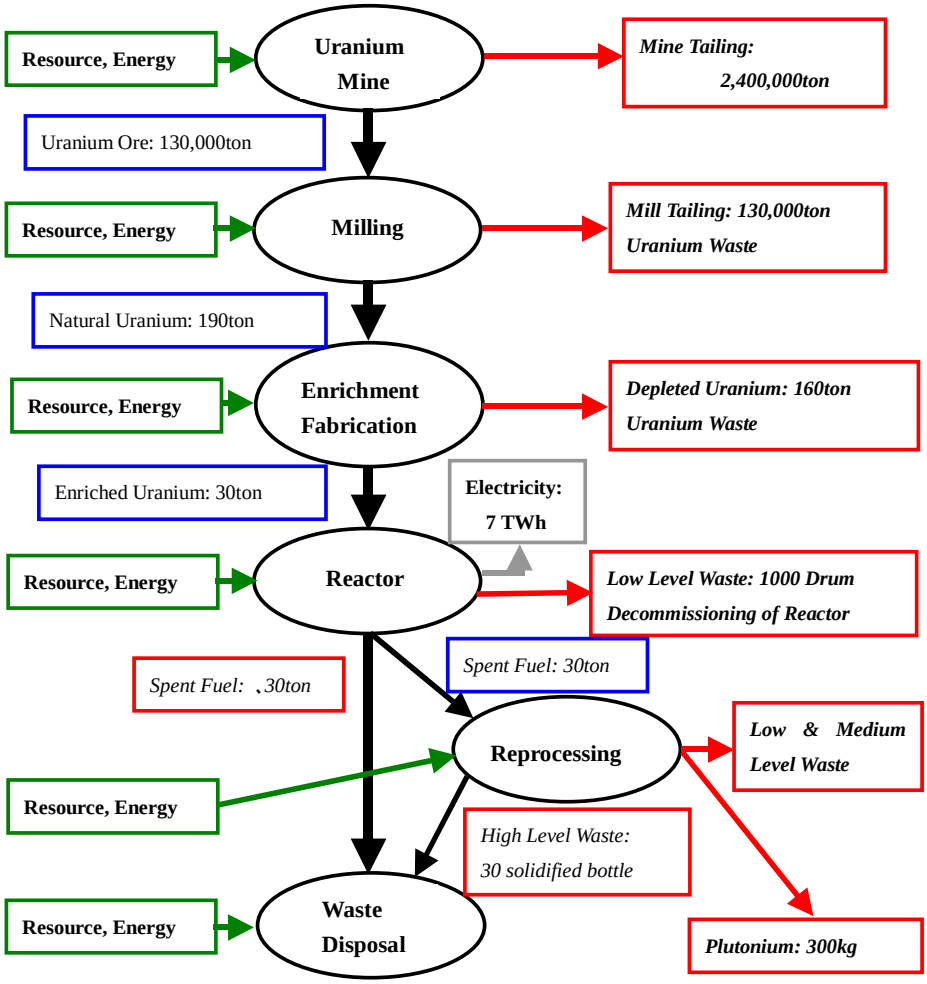


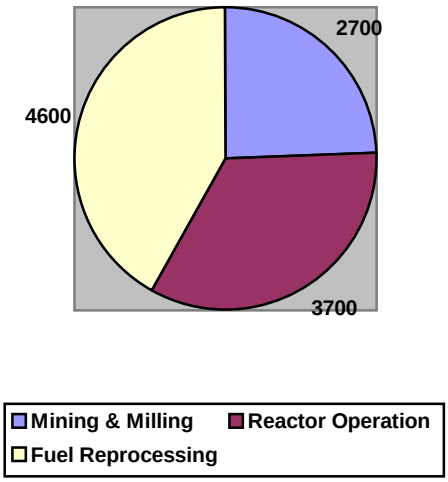
Figure 12 Process flow and radioactive disposals produced from 1000MWe·y nuclear power generation.

the world. Besides, it is not avoided that the inhabitant gets exposure, if the appropriate management does not be done.

The exposure by the utilization of nuclear energy is generated in here and there. As the evaluation by the United Nations scientific committee[6] is shown in Figure 13, almost 25% of total exposure which the mankind received in a past occurs from the pollution in the uranium mine which is uppermost stream of utilization of nuclear energy. Besides, this pollution becomes largest exposure source for the long-term exposure of human beings, since it occurs from the uranium of half-life of 4.5 billion year.

I want to add again that the exposure of labors in the mine, including Jadugoda, will be the largest problem. I hope that in the future the sufficient investigation will be done and the result will be fully announced, and then the necessary relief measures will be taken.

Figure 13 The committed dose equivalent from the use of nuclear power generation up to the present, estimated by UNSCEAR [6] [person · Sv]



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See also following URL. http://www-j.rri.kyoto-u.ac.jp/NSRG/genpatu/india.htm

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