Discrepancy between the Contamination Pattern and the Daily Radiation Survey Data Used for External Dose Estimation of Evacuees from the 30-km Zone

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Introduction

A series of the first explosions at the Chernobyl-4 reactor occurred at 01:23:45-50 on April 26, 1986. The large amount of radioactivity release continued about 10 days due to the graphite fire at the reactor core. Figure 1 shows daily release of radioactivity based on the data given in the report the USSR government presented to IAEA in August 1966 (1986 USSR Report) [1] Depending on the fluctuation of wind direction, radioactive plumes flew to various directions from the destroyed reactor. Figure 2 indicates changes of wind directions and the contamination pattern during the period of large radioactivity release [2]. On April 26, the first strong radioactive plume moved to the west direction. Then, on April 27-28, radioactive plumes contaminated north-west and north areas. The basic pattern of the contamination near the Chernobyl power plant (ChNPP) was considered to be formed in the first three days. After that, the plumes direction moved to east and south directions.

On April 27, the next day the accident, the Pripyat city where workers of ChNPP were living was evacuated. Meanwhile, the people living in settlements other than Pripyat were left uninformed about the accident. It was on May 2 that the evacuation of all people within the 30-km zone was decided [3]. The evacuation finished around May 10. That is, these evacuees had been in the strong contamination for one week or more. Therefore, these evacuees were supposed to receive far more radiation than Pripyat citizens.

Table 1 shows estimates of average external dose for evacuees from the 30-km zone given in 1986 USSR Report. It is noted that the average dose of 26,200 evacuees from 19 settlements within 15 km from ChNPP was 450 mSv, which is 14 times larger than the value for Pripyat citizens of 33 mSv. Unfortunately, detailed information how to obtain these values was not given in the report.

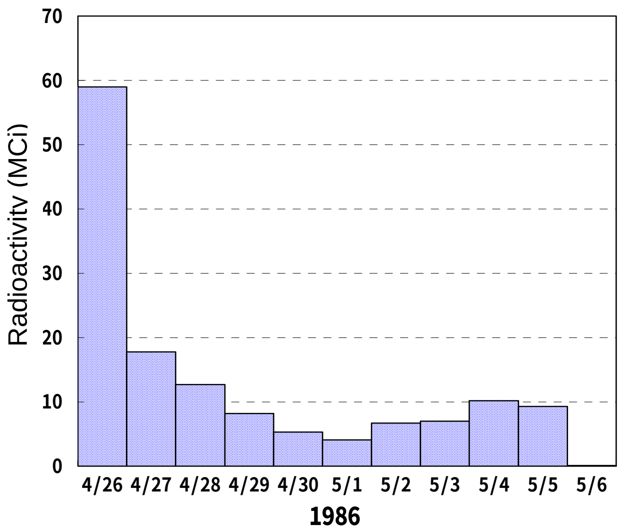

Fig.1. Daily radioactivity release, excluding noble gases.

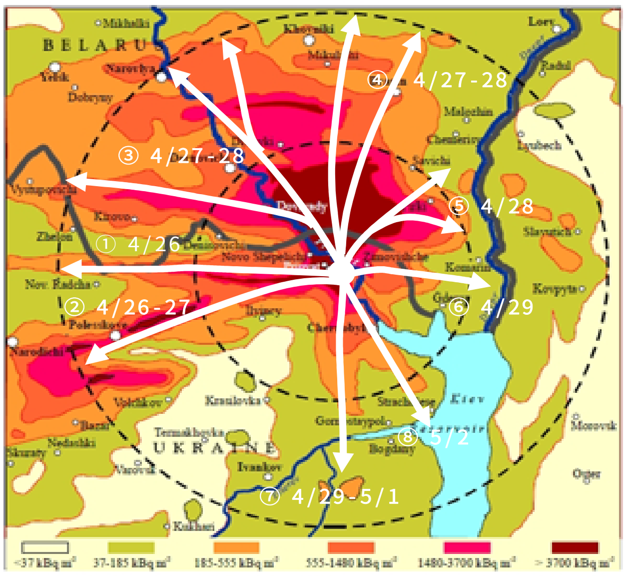

Fig.2. Daily direction of radioactive plumes on the back of ^{137}Cs contamination map. Made from Izrael's paper [2]

Table 1. Average external dose of evacuees reported in the 1986 USSR report

Distance from the Chernobyl site	Number of Settlement	Population (persons)	Average external dose(mSv)
3 - 6 km	(Pripayt)	45,000	33
3 - 7 km	5	7,000	540
7 - 10 km	4	9,000	460
10 15 km	10	8,200	350
15 - 20 km	16	11,600	52
20 - 25 km	20	14,900	60
25 - 30 km	16	39,200	46

On the other hand, Chernobyl Forum, which was organized by IAEA and other international institutions to summarize 20 years of investigation on the consequences of the Chernobyl accident, reported that the average dose of the evacuees from the 30-km zone was 20-30 mSv and the maximum was several hundred mSv [4]. The main source of the Chernobyl Forum report was considered to be the study by Likhtarev et.al for Ukrainian evacuees [5], in which the average external doses of 11.5 and 18.2 mSv were estimated for evacuees from Pripyat and other-than-Pripyat, respectively, by combining daily radiation survey data in settlements within the 30-km zone with individual questionnaires on the behavior after the accident. It is noteworthy that the dose ratio of Pripyat to other-than-Pripyat is obtained 1.6, while the corresponding ratio of the 1986 USSR report is 4.8. Although the detailed data about in the Pripyat city was shown in reference, the daily radiation survey data were not shown for other-than-Pripyat settlements in the 30-km zone [5].

Radiation survey data within the 30-km on May 1, 1986

In March, 1986, at an international conference for the 10th anniversary of the Chernobyl accident held in Minsk, an interesting map (Fig. 3) was presented about radiation exposure survey data on May 1, 1986, five days after the accident in settlements within the 30-km zone was released [6]. The maximum of 3,306 µGy/h

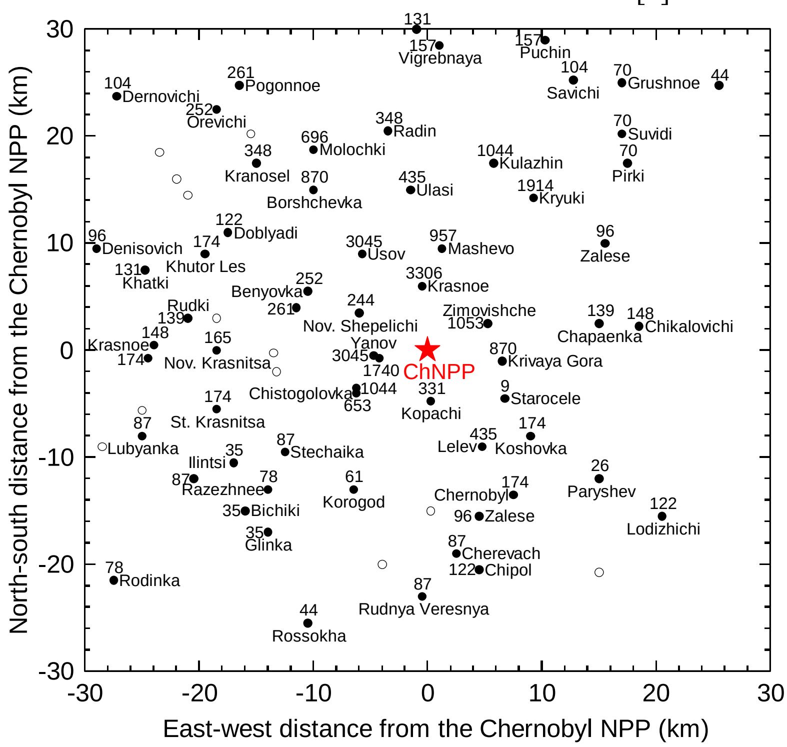

Fig.3. Dose rate in the 30-km zone on May 1, 1986,µGy/h.

(380 mR/h) was seen in Krasnoe village located 6 km north of ChNPP. This dose rate equals 80 mGy/day.

In the same report, the time trend of dose rate per unit ^{137}Cs deposition measured at Khoiniki located 50 km north from ChNPP was also presented, which was shown as diamonds in Fig. 4. The solid curve (Calculation 1) is calculation by Imanaka, assuming fallout composition given by Izrael et.al [7] as well as dose rate conversion factors (Table 2) [8]. The dotted curve is obtained by reducing the deposition ratio of Zr-Nb to half of Izrael's values. Calculation 2 could reconstruct the dose rate change well at the early stage of the contamination.

Assuming that all radioactive contamination in Krasnoe occurred at 12:00 on April 27 and all residents were evacuated at 12:00 May 3, Imanaka estimated the average dose in Karasnoe to be of 0.48 Sv, including internal exposure from inhalation. In the process to obtain this vale, the average body shielding coefficient of 0.8 (Sv/Gy) and the average occupation-shielding factor of 0.62 were used from the Likhtarev paper [5]. Taking into consideration the distribution of individual doses, it was concluded that 18 % of residents in Krasnoe could receive external dose more than 1 Sv, a criterion of acute radiation syndrome [8].

Our estimates of radiation dose for evacuees agreed with those given in 1986 USSR report, while about 3 times larger than those by Likhtarev et.al.

Table 2. Relative deposition composition (^{137}Cs=1) and dose conversion factor of nuclides deposited around the Chernobyl site.

Nuclide	Half life	Relative composition*	Dose factor (μR/h)/(Ci/km^2)
^{91}Sr	9.7 h	1.2	20
^{95}Zr	65.5 d	3.3	29
^{97}Zr	17 h	1.6	29
^{95}Nb	35 d	3.3	15
^{99}Mo	2.75 d	7.5	2.8
^{103}Ru	39 d	5.3	9.6
^{106}Ru	367 d	1.3	3.7
^{131}I	8.04 d	20	7.6
^{133}I	21 h	40	12
^{135}I	6.7 h	35	34
^{132}Te	3.25 d	33	46
^{134}Cs	2.05 y	0.5	29
^{136}Cs	13 d	0.3	39
^{137}Cs	30 y	1	11
^{140}Ba	12.8 d	3.6	43
^{140}La	1.67 d	3.6	39
^{141}Ce	32.3 d	3.5	1.8
^{143}Ce	1.38 d	3.1	4.9
^{144}Ce	284 d	2	0.55

*; Decay-adjusted at the time of the accident

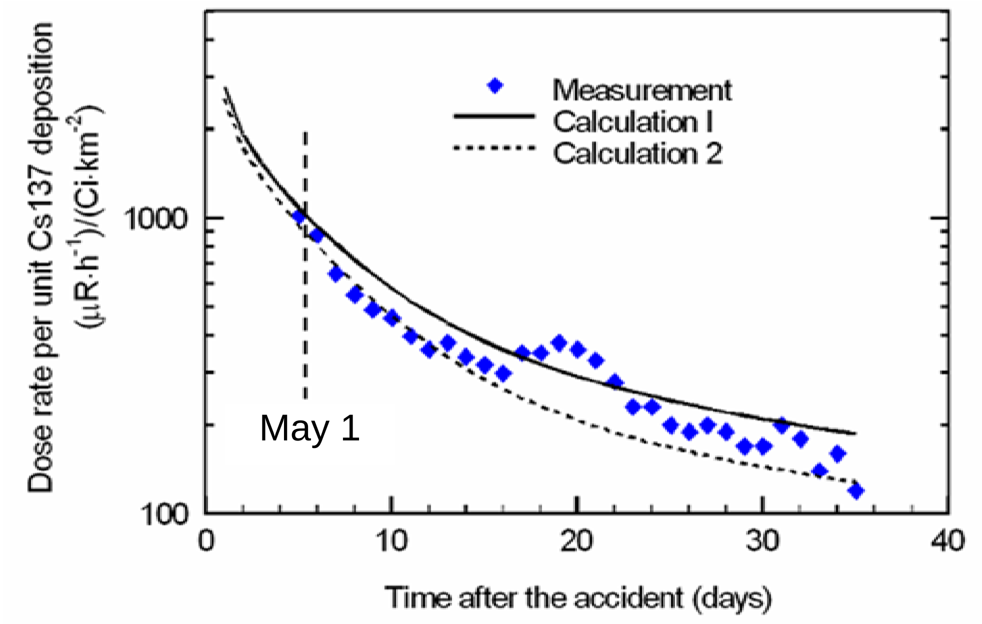

Fig. 4. Dose rate change in Khoiniki normalized per unit deposition of ^{137}Cs.

Radiation survey data within the 30-km zone on other days

In 2002, Muck et.al at GSF, Germany together with Ukrainian scientists published estimates of on inhalation dose for the evacuees from the 30-km zone [9], in which daily radiation survey data for the first two weeks in the 30-km zone were indicated. More details were found in GSF report [10]. Parts of daily radiation survey data are plotted in Fig. 5, divided directions around ChNPP into five sectors.

It is extremely surprising that maxima of exposure rate in Fig. 5 were not seen in April 26-28 when the strongest plumes were released, but in later days. For example, in two settlements of Chitogolovka and Tolsty Les in Sector-A (West) where the first radioactive plume passed over on April 26, the maximum of radiation exposure were recoded on May 3 and May 4, respectively, and no serious radiation increase was recorded in the firth three days. It is also noted that in Sector-C (North) the maximum value (3,300 μGy/h) in Krasnoe is seen on May 1, which corresponds to the maximum in Fig. 3 of 3,306 μGy/h.

Considering the plume directions and ^{137}Cs contamination pattern shown in Fig.2, it is difficult to accept the exposure rate trends of Fig. 5 as real ones, in spite of the description [6] that radiation survey was carried out every day in all settlements in the 30-km zone after the accident. Preferably we should consider that the

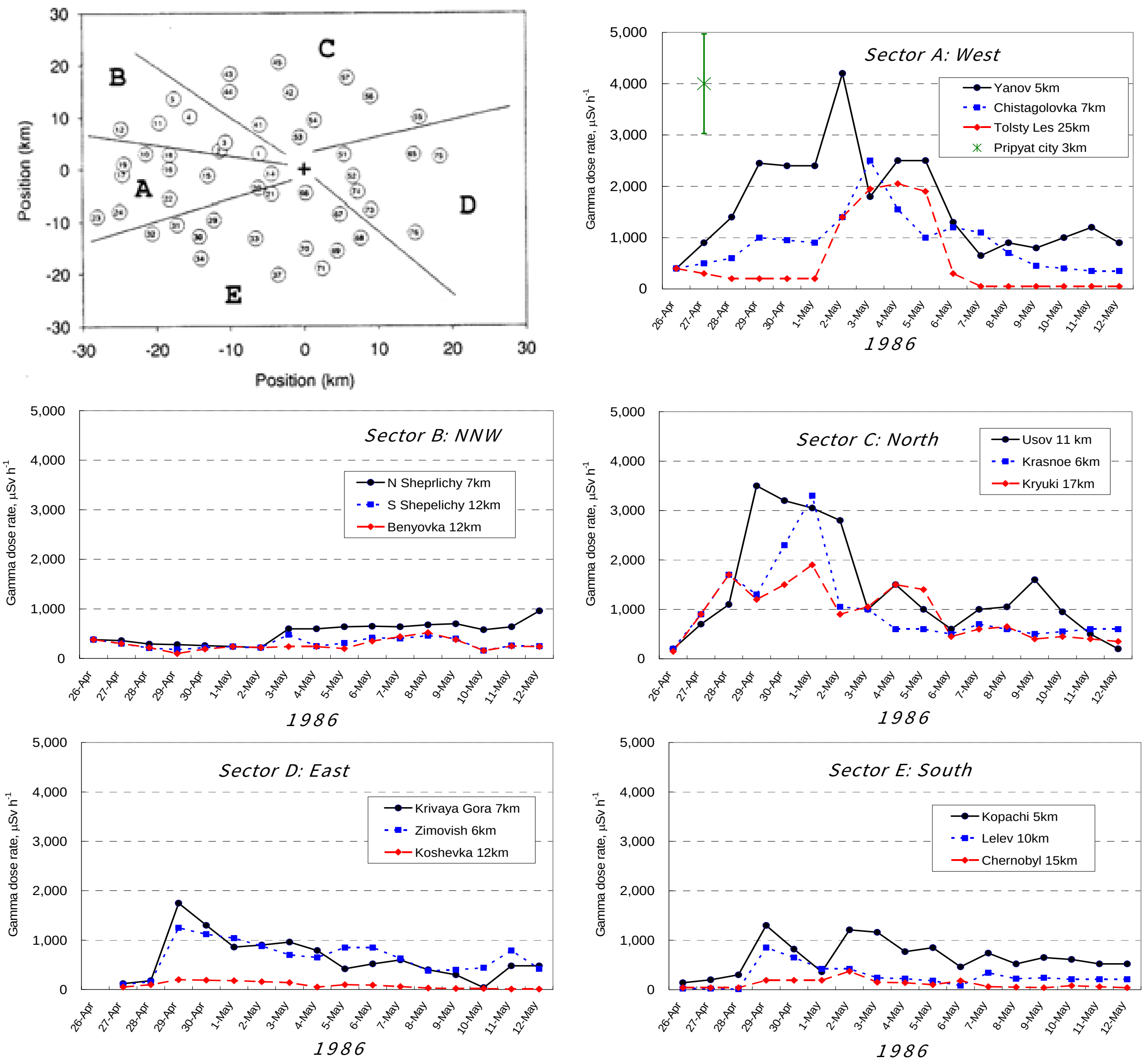

Fig. 5. Dose rate monitoring data supposed to be used in the previous study. A-E: direction sector.

monitoring activities in the first week for settlements within the 30-km zone were quite insufficient. Therefore, dose estimations that directly used the data of Fig. 5 could lead to underestimation of real values.

Our new estimation of external dose for evacuees

After detailed investigation of the radiation survey data shown in Fig. 5, we assumed that, although the plotted data in the first three days could not be accepted, the data of later period could be used to estimate external radiation of the evacuees, by extrapolating them to the earlier period. Examples of such extrapolation for Chistagolovka and Novaya Shepelichy villages are shown as dashed lines in Fig. 6. Then we assumed that the deposition occurred at a time at 12:00 April 26 and 00:00 April 27 in Chistagolovka and Novaya Shepelichy, respectively. The evacuation time at 12:00 May 3 was assumed for both villages. The results of external dose estimation based on the extrapolation method are shown in Table 3 (Model-1) together with estimates for several other settlements in different sectors.

We also applied another method to estimate external dose for evacuees (Method-2), in which external exposure was evaluated based on the amount of total ^{137}Cs deposition given in ref [10], relative deposition composition [11] and dose rate conversion factors (Table 2). The results by the Model-2 are also shown in Table 3. A reasonable agreement can be seen between the results by Method-1 and by Method-2.

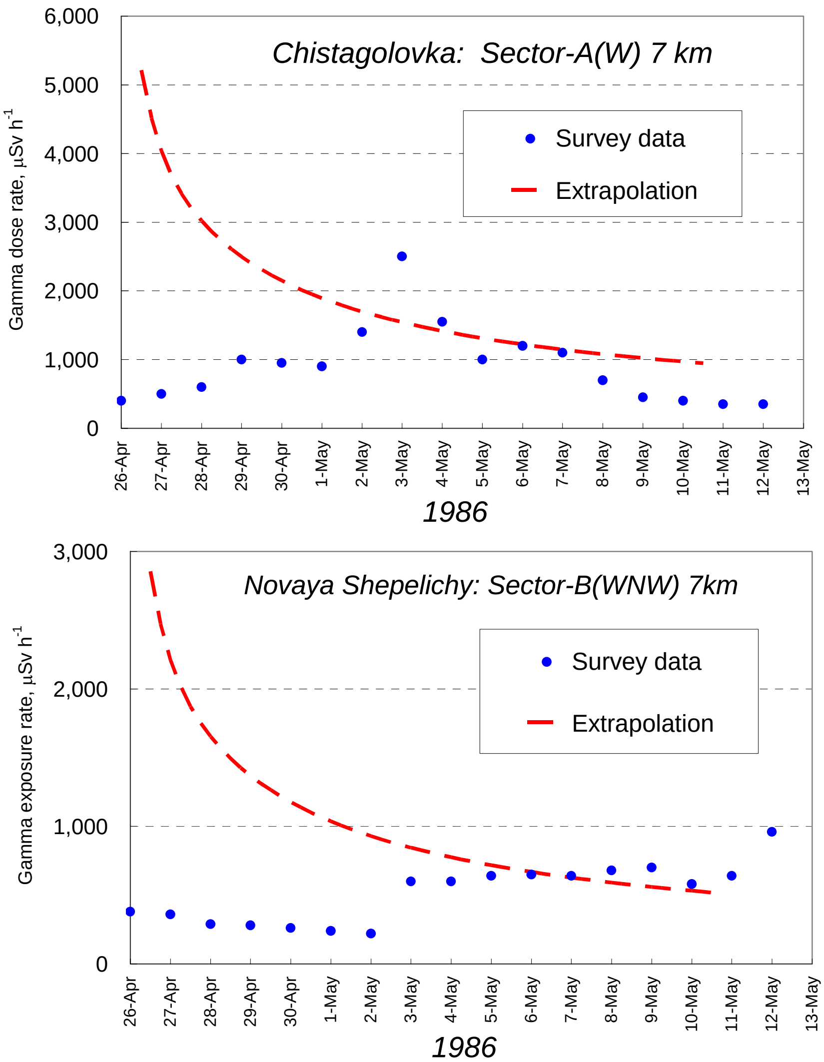

Fig. 6. Extrapolation of radiation survey data to the earlier period after the accident. Survey data between May 1 to May 7 were used for extrapolation of Chistagolovak. May 3 – May 9 was used for Novaya Shepelichy.

Table3 New external dose estimation based on two different methods as well as previous GSF/Ukraine values.

Sector	Village	Distance, km	Time of deposition	Date of evacuation	^{137}Cs density, kBq/m^2	Average external dose until evacuation, mSv		
						Present study		GSF/Ukraine (2000)
						Method-1	Method-2	
(A) West	Yanov	5	12:00April26	12:00April29	18,450	180	250	9.5
	Chistogolovka	7	12:00April26	12:00May 3	10,000	230	200	70
(B) WNW	N.Shepelichy	7	00:00April27	12:00May 3	3,530	96	72	13
	S.Shepelichy	12	00:00April27	12:00May 3	830	58	12	23
(C) North	Kryuki	17	00:00April28	12:00May 5	15,090	140	200	−
	Usov	11	00:00April28	12:00May 3	4,790	160	55	154
(D) East	Kryvaya Gora	7	00:00April29	12:00May 4	2,150	68	59	51
	Zimnovishe	6	00:00April29	12:00May 3	4,020	55	95	42
(E) South	Kopachi	5	00:00April29	12:00May 4	2,690	59	65	53
	Chernobyl	15	00:00April29	12:00May 5	1,780	14	14	6

Compared with the values given by GDF/Ukraine group, our new estimations indicate significantly larger values in Sector-A and Sector-Bt, while values in other sectors indicate agreement each other within an acceptable range. Considering that radioactive plumes began to contaminate Direction-D (East) and –E (South) after April 29, the agreement seen in Sector-D and –E might may reflect the situation that the systematic radiation survey in contaminate settlements other than Pripyat became effective at this period.

Conclusion

A clear discrepancy is seen between the contamination pattern around ChNPP and the daily radiation survey data used to evaluate external dose of evacuees. Reassessment is necessary especially west and north-west directions from ChNPP.

Refereces

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