RESULTS OF LARGE SCALE THYROID DOSE RECONSTRUCTION IN UKRAINE

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Abstract. In 1993, the Ukrainian Ministry on Chernobyl Affairs initiated a large scale reconstruction of thyroid exposures to radioiodine after the Chernobyl accident. The objective was to provide the state policy on social compensations with a scientific background. About 7,000 settlements from five contaminated oblasts have gotten certificates of thyroid exposure since then. Certificates contain estimates of the average thyroid dose from ^{131}I for seven age groups. The primary dose estimates used about 150,000 direct measurements of the ^{131}I activity in the thyroid glands of inhabitants from Chernihivs'ka, Kyivs'ka, Zhytomyrs'ka, and also Vinnyts'ka oblasts. Parameters of the assumed intake function were related to environmental and questionnaire data. The dose reconstruction for the remaining territory was based on empirical relations between intake function parameters and the ^{137}Cs deposition. The relationship was specified by the distance and the direction to the Chernobyl Nuclear Power Plant. The relations were first derived for territories with direct measurements and then they were spread on other areas using daily iodine releases and atmospheric transportation routes. The results of the dose reconstruction allowed to mark zones on the territory of Ukraine according to the average levels of thyroid exposures. These zones underlay a policy of post-accidental health care and social compensations. Another important application of the thyroid dose reconstruction is the radiation risk assessment of thyroid cancer among people exposed during childhood due to the Chernobyl accident.

1. INTRODUCTION

Large areas of Ukraine were contaminated by the radioactive fallout of the Chernobyl reactor accident in 1986. Due to its chemical and physical properties, among the radioisotopes released, ^{131}I contributed significantly to the exposure of the population. Thyroid exposure from ^{131}I, especially to children's thyroid glands, is one of the most important consequences of the Chernobyl accident.

More than 150,000 direct measurements of thyroid ^{131}I activities were carried out by special dosimetric teams under the guidance of emergency group specialists of the Ukrainian Health Care Ministry during May and June of 1986

in Ukraine. Despite a large number of the thyroid activity measurements, 0.2% of inhabitants were measured in oblasts with direct measurements only and wide areas suffered strongly were not covered with the thyroid exposure monitoring at all. Therefore a reconstruction of the thyroid doses due to radioiodine incorporation is of special importance. In 1993, the Ukrainian Ministry on Chernobyl Affairs had initiated large scale reconstruction of thyroid exposure to radioiodine. The objective was to provide the state policy on social compensations aftermath accident with scientific background.

The paper presents some results of the thyroid dose reconstruction in five oblasts from northern Ukraine: Chernihivs'ka[1], Kyivs'ka, Zhytomyrs'ka, Vinnyts'ka, Cherkas'ka. Up to the end of November 1995, 6,773 settlements from these oblasts have gotten certificates of thyroid exposure. Certificate contains the estimates of average thyroid dose from ^{131}I for seven age groups. Table 1 shows the classification and age intervals in the age groups of the thyroid dose certificate.

Table 1. The age groups in thyroid dose sertificate for settlment

Group	1	2	3	4	5	6	7
Year of birth	1986	1983–1985	1979–1982	1975–1978	1971–1974	1968–1970	< 1968
Age at the time of the accident	<1	1–3	4–7	8–11	12–15	16–18	>18

The work on the dose recovery was carried out in series: first, for oblasts with the majority of direct measurements – Chernihivs'ka, Kyivs'ka and Zhytomyrs'ka. The exception was the settlements inside the 30-km zone and city Kiyv that woud be the goal of future investigations.

Then, the dose reconstruction was fulfiled for oblasts more distant from Chernobyl Nuclear Power Plant (NPP) - Vinnyts'ka and Cherkas'ka oblasts. They had only a few direct measurements. The investigation on the thyroid doses recovery is being in process and up to the end of 1995 two additional oblasts – Rivnens'ka and Volyns'ka – will get certificates of thyroid exposure.

2. DATA USED FOR THYROID DOSE RECONSTRUCTION

2.1. Direct measurements of thyroid activities

The primary dose estimates used about 150,000 direct measurements of the ^{131}I activity in the thyroid glands of inhabitants from Chernihivs'ka, Kyivs'ka, Zhytomyrs'ka, and also Vinnyts'ka oblasts. [1]. The settlements of Ukraine in 20 different raions, and also city Kyiv and town Prypiat', with measurements are indicated in Fig 1. The thyroid activity measurements were performed using different types of devices listed in Table 2.

[1] In the paper we use latin transliteration from Ukrainian language in names of settlements and regions, except name *Chernobyl*.

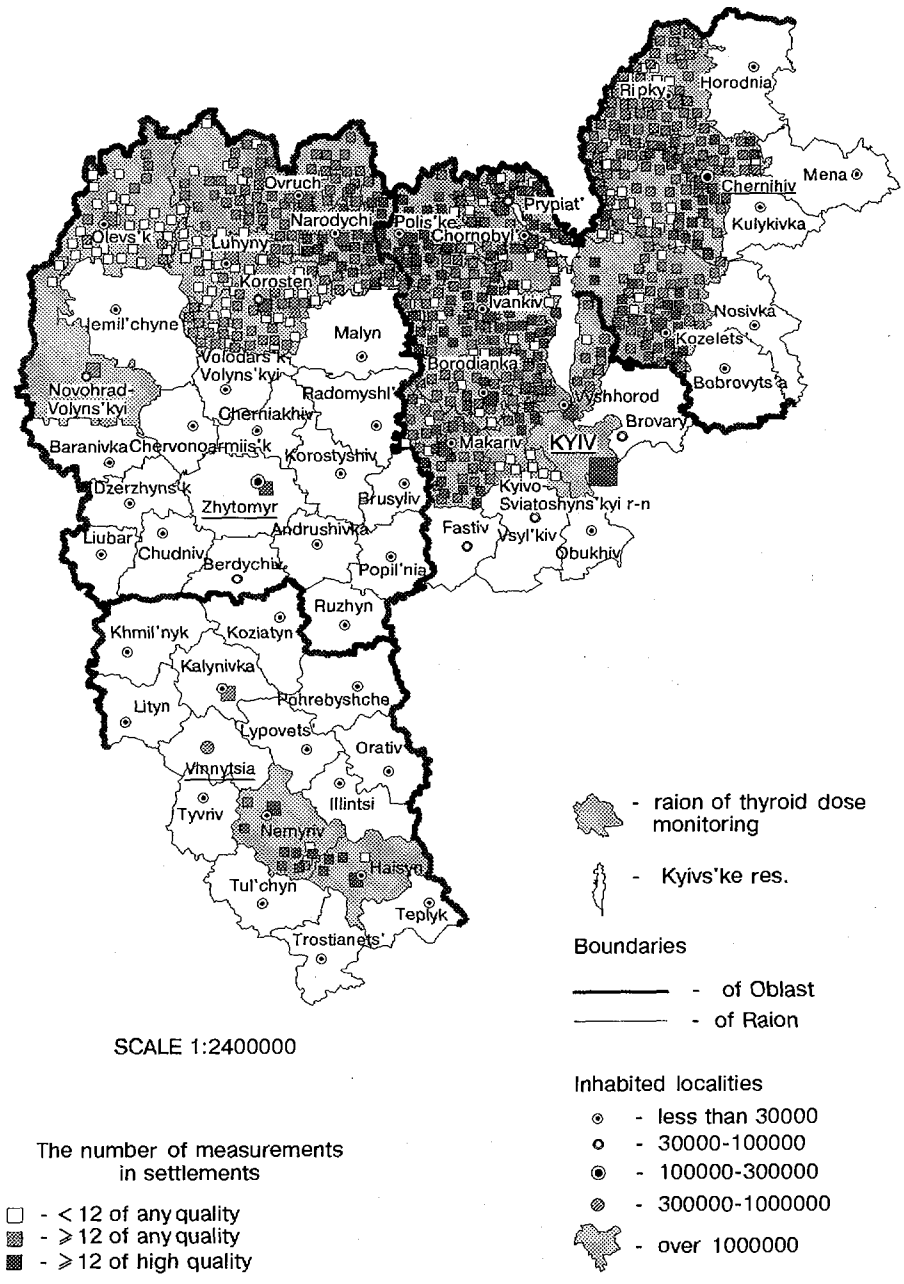

Fig.1. Spatial distribution of the thyroid activity measurements in Ukraine during a period of May-June 1986

Table 2 Devices used for ^{131}I thyroid activities monitoring in Ukraine

Device	Method of measurement	Detector type	Detector dimensions (mm)	Analyzer
SRP-68-01	exposure rate	NaI(T1)	30×25	– [a]
DSU 2-1/DSU-68	spectrometer	NaI(Tl)	63×63	Single-channel
GTRM 01c	spectrometer	NaI(Tl)	40×40	Single-channel
NK 150	spectrometer	NaI(Tl)	25×25	Single-channel
NK 350	spectrometer	NaI(Tl)	25×25	Single-channel
UR 1-1/UR 1-3	spectrometer	NaI(Tl)	63×63a	Four-channel

[a] This device is equipped with two detectors of this size

About 56,000 people from the whole data set were monitored by means of spectrometric techniques used a referent source for calibration. About 35,000 measurements of them were combined in series allowing a statistical analysis of the reliability of these measurements [2]. For the non-spectrometric techniques 4886 measurements were combined in a series with a referent source. Only the serial non-spectrometric measurements with repeated calibration give some indication as to the quality of these non-spectrometric measurements. The analysis of the selected serial reference-source measurements shows that the majority of these measurements (82%) is high or acceptable quality. Therefore the results of non-serial spectrometric technique were defined as high quality individual measurements. The results of the non-serial non-spectrometric measurements were defined as the results of low quality because of the lack of possibility to estimate the reliability of these measurements. .

Table 3 shows the quantity of individual measurements with high and low quality in raions of thyroid monitoring.

2.2. Settlement locations and ^{137}Cs deposition

For the dose reconstruction we use the data on ^{137}Cs soil contamination in every settlement collected by Ukrainian Ministry on Chernobyl Affairs [3]. A special data base has been created to collect the data on ^{137}Cs deposition to soil and geographic coordinates of every settlement for territory under certification. Fig. 2 presents the map of the northern part of Ukraine with izolines of ^{137}Cs deposition.

2.3. Data on behavior in May 1986

The results of large-scale quiz on the individual behavior during May 1986 were used for thyroid dose reconstruction. Fig. 3 presents this questionnaire. The questions especially concerned the following areas: residence (staying in- and outdoors, time and duration of leaving the contaminated territory); the intake of stable iodine; the consumption of fresh milk (source and daily consumption); the consumption of leafy vegetables (origin and daily consumption). The Questionnaire data base contains about 23,000 individual records.

Table 3. Number of the measurements of different quality in raions and cities with direct thyroid activity measurements in Ukraine

Oblast	Raion	Quality	Number of measurements in age group (according to thyroid dose certificate)						
			1	2	3	4	5	6	7
Vinnyts'ka	Haisyns'kyi	high	16	115	122	110	96	-[a]	16
		low	-	-	-	68	73	-	-
	Nemyrivs'kyi	high	21	227	178	170	120	-	18
		low	-	35	52	40	26	-	-
	Kalynivka town	high	-	-	-	-	-	-	-
		low	-	47	262	18	0	-	38
Zhytomyrs'ka	Zhytomyrs'kyi	high	-	16	104	72	87	-	48
		low	-	-	-	-	-	-	-
	Korostens'kyi	high	-	-	98	111	105	-	-
		low	51	532	747	3024	3119	401	656
	Luhyns'kyi	high	-	-	-	-	-	-	-
		low	-	-	-	-	-	-	155
	Novohrad-	high	-	-	-	-	-	-	-
	Volyns'kyi	low	-	-	15	109	109	-	-
	Narodychs'kyi	high	15	111	171	36	57	76	3426
		low	129	1273	1557	1815	1889	953	8000
	Ovruchs'kyi	high	-	17	51	41	60	-	34
		low	199	1900	2534	3747	4019	602	7916
	Olevs'kyi	high	-	-	-	-	-	-	-
		low	-	98	155	164	177	21	252
Kyivs'ka	Borodians'kyi	high	-	-	18	146	105	-	-
		low	-	49	172	1931	2119	564	20
	Vyshhorods'kyi	high	-	-	27	893	1010	366	-
		low	-	177	301	1609	1954	499	79
	Kyiv city	high	-	24	129	1229	1304	12	29
		low	-	83	127	904	711	-	158
	Ivankivs'kyi	high	-	152	214	224	218	49	-
		low	28	196	282	1040	1303	351	233
	Kyivo-	high	-	59	187	1028	1044	-	-
	Sviatoshyns'kyi	low	-	12	51	157	185	21	13
	Makarivs'kyi	high	-	-	13	231	195	88	-
		low	-	25	103	1505	1737	363	32
	Polis'kyi	high	-	164	325	438	563	153	-
		low	62	410	446	606	701	337	356
	Prypiat' town	high	-	139	266	613	822	169	17
		low	35	378	627	584	464	142	386
	Chornobyl's'kyi	high	13	166	203	714	926	194	-
		low	29	391	503	443	470	96	500
Chernihivs'ka	Kozelets'kyi	high	37	374	380	307	421	381	1080
		low	138	1555	2090	1878	2175	356	2641
	Ripkyns'kyi	high	-	-	-	15	22	-	-
		low	148	1293	1756	2264	2156	536	3480
	Chernihivs'kyi	high	86	1074	1506	1190	930	145	302
		low	223	2395	3487	4041	3953	657	2355

[a] – less 12 measurements

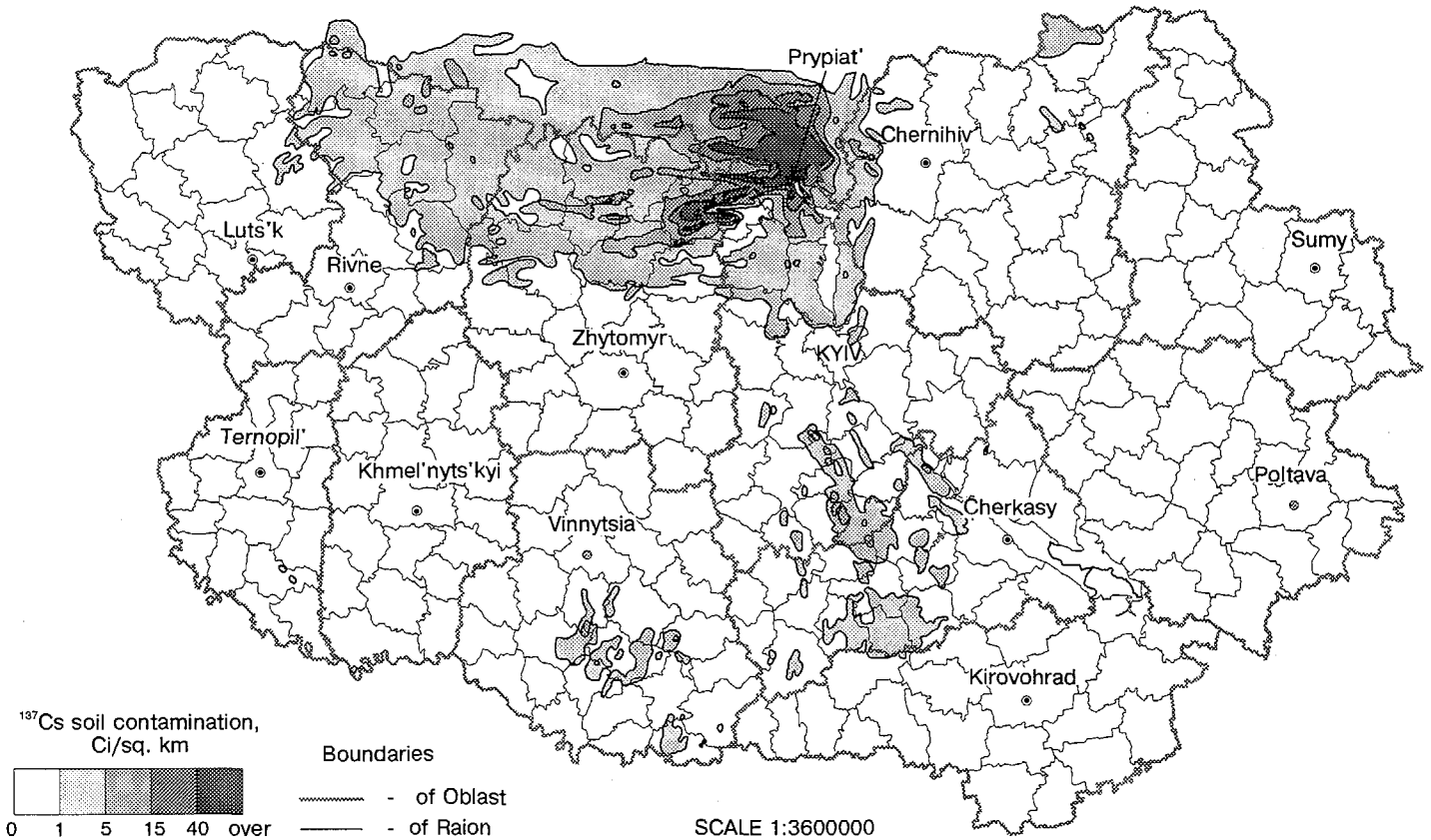

Fig.2. ^{137}Cs soil contamination of the northern part of Ukraine (12 oblasts)

QUESTIONNAIRE

1. Personalities

Surname	Name	Patronymic

Sex | Date of birth (day, month, year)

Address at the time of the accident

Address at present, phone

2. Peculiar measurement

Were you measured in May-June 1986 in respect to thyroid dose monitoring?- "yes", "no" (underline); if "yes", where?

3.Countermeasures

3.1 Countermeasures (underline)	wet cleaning, bathing, cloth change,	outdoor time restriction, windows closing

if other (write): _____ Since what time?(date)_____

3.2 Stable iodine administration.

Cross in the table (right) days when you consume stable iodine (even approximately)

TABLE - CALENDAR (APRIL-MAY 1986)

mo	tu	we	th	fr	st	su
					26	27
28	29	30	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

4. Residence since April 26 to June 1986 (in details)

Residence			Type of a building			Date (day, month, year)	
oblast'	region	settlement	one-floor	many-storied		arrival	depature
			stone/wooden	brick	floor		

Fig. 3 Form of questionnaire used for the thyroid dose reconstraction

5.Behaviour

Days	How many hours did you spend (in average)		
	outdoor	indoor with opened windows	indoor with closed windows
26 - 27 April (days off)			
28 - 30 April (working days)			
1 - 4 May (holiday)			
5 - 8 May (working days)			
9 - 11 May (holiday)			
12 - 16 May (working days)			
17 - 18 May (days off)			
19 - 23 May (working days)			
end of May			

6. Consumption of milk (milk products) and of leafy vegetables at the time of the accident.

In table (left side) choose and underline the source of consumed milk (code). In case of absence of appropriate name in the list put it in the row #7.

In table (right side) choose and underline the code of the consumed vegetables. In case of absence of appropriate name in the list put it in the row #7.

Code	Origine
1	not consumed
2	state milk-stores
3	milk from private farm
4	Goat's milk
5	mother's milk
6	baby mixtures
7	(add needed)

Code	Origine
1	not consumed
2	parsley dill
3	lettuce
4	spinach
5	sorrel
6	nettle
7	(add needed)

Fill the following table (use choosen code). *Put the code* into appropriate column " Daily milk consumption " and " Daily consumption of leafy vegetables "

Days	Settlement where you stayed	Daily milk consumption					Daily consumption of leafy vegetables			
		11	0.5 l	1 glass	0.5 glass	Other (enter)	50 g	100 g	1-2 leafs	Other (enter)
26 - 27 April (days off)										
28 - 30 April (working days)										
1 - 4 May (holiday)										
5 - 8 May (working days)										
9 - 11 May (holiday)										
12 - 16 May (working days)										
17 - 18 May (days off)										
19 - 23 May (working days)										
end of May										

7. How do you remember your behaviour in May-June 1986 good (underline):

1.Good	2.Satisfactory	3.Badly	4.Hardly

Fig. 3, continued

3. RESULTS OF DOSE RECONSTRUCTION

Two approaches to the dose reconstruction procedure were used. The first one was applied for three oblasts closest to Prypiat' which contained the majority of measurements carried out in May and June of 1986. They were Chernihivs'ka, Zhytomyrs'ka and Kyivs'ka oblasts. Technique has been reported explicitly in [4]. Fig. 4 shows the scheme of this method. The essence of this approach is an using the relationships between the thyroid doses and the ^{137}Cs deposition as well as the location relative to the Chernobyl NPP. Those empirical relationships was estimated for the territory with direct thyroid activity measurements and then they were applied to the territory without measurements.

Questionnaire data were used to check whether the behavior of the population in raions without direct measurements is comparable with that of the rest of the population.

The results of such dose reconstruction were the age-specific average thyroid exposure doses for every settlement in three oblasts (except the settlements of 30-km zone and the city of Kyiv). The obtained data reveal the spatial dose distribution in different age groups of the population. Fig. 5 shows the spatial dose distribution for children born between 1983 and 1985 who dwelt in Chernihivs'ka, Zhytomyrs'ka and Kyivs'ka oblasts.

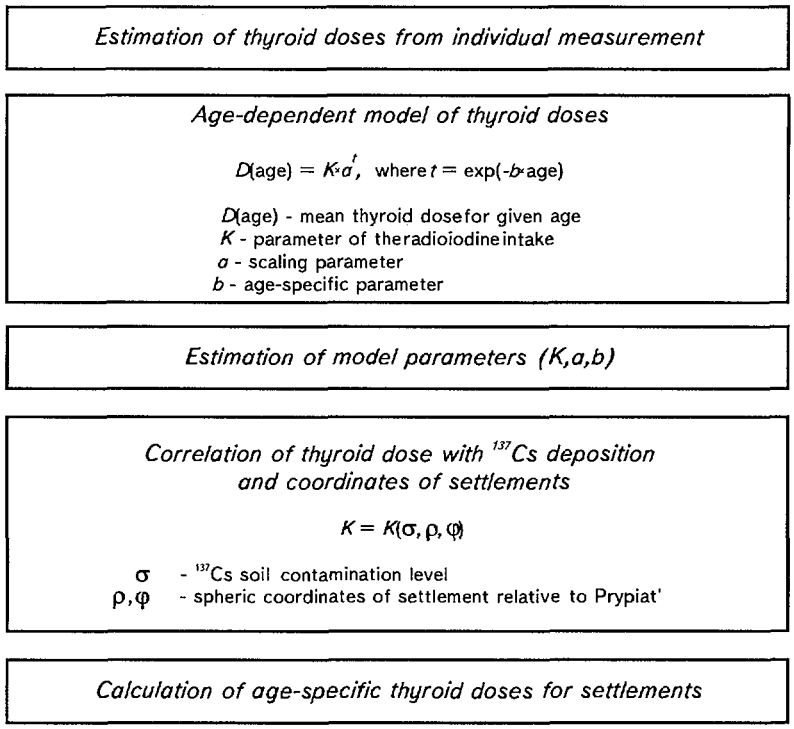

Fig.4. Scheme of thyroid dose reconstruction for population of Chernihivs'ka, Kyivs'ka, and Zhytomyrs'ka oblasts

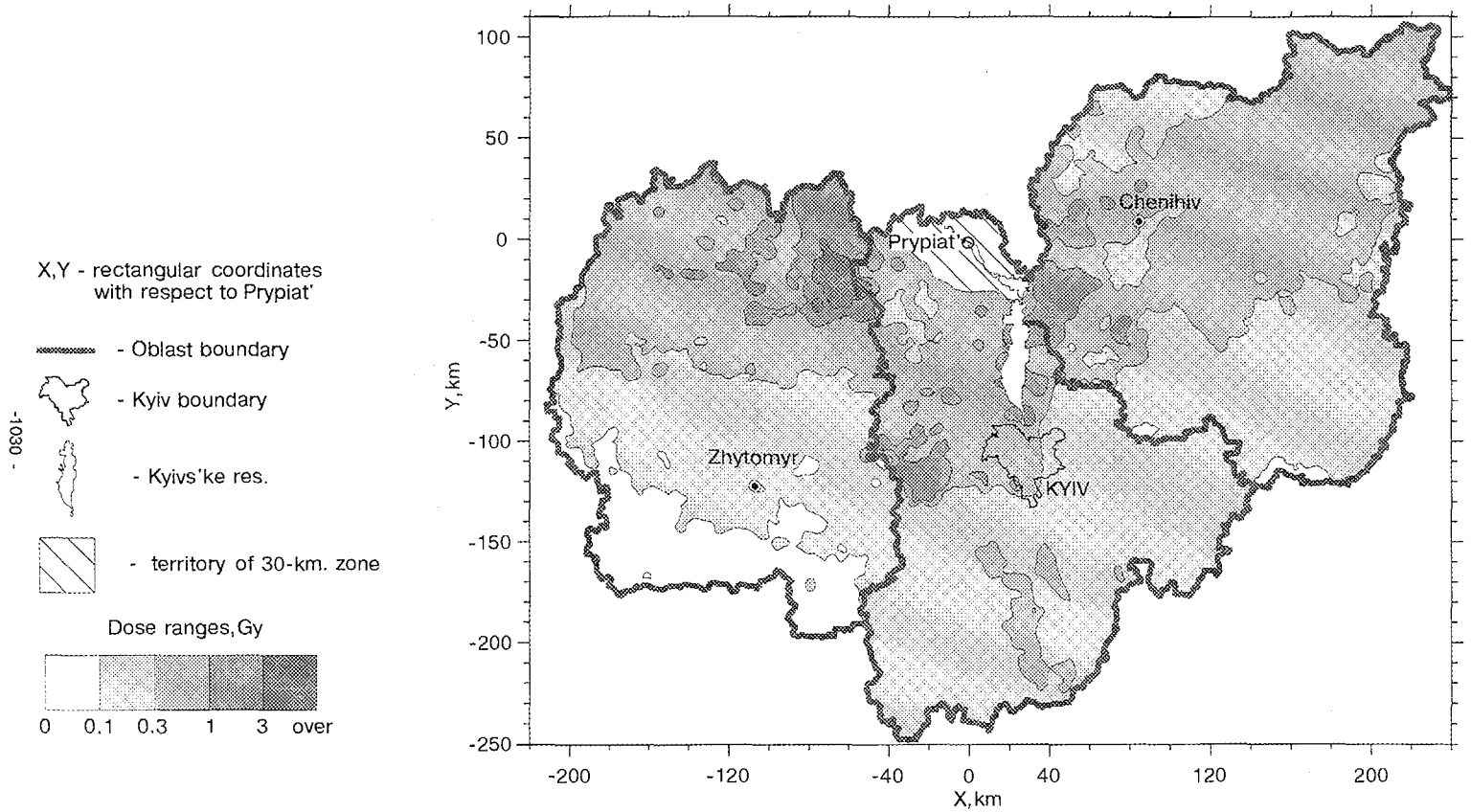

Fig.5. Thyroid doses from ^{131}I to children born between 1983 and 1985 in Kyivs'ka, Chernihivs'ka and Zhytomyrs'ka oblasts

The second approach was applied for oblasts beyond the area of the thyroid activities monitoring - Vinnyts'ka and Cherkas'ka oblasts. Fig. 6 shows the main points of this approach.

Dose reconstruction for this territory was based on empirical relationship between the parameters of the ^{131}I thyroid content model, which indicate the intensity of the accidental environmental contamination, and ^{137}Cs local deposition. Relationship was specified by distance and azimuth to the Chernobyl NPP, by atmospheric transportation routes of radioactive releases, by the day of the iodine stage of the accident.

According to this approach the territory in question was subdivided by the sectors and segments with ^{131}I intake function, suggested to be the uniform one. The subdivision was based on ^{137}Cs soil contamination, the source term of the accident [5], the quantity of the direct thyroid activity measurements, distance and azimuth to Chernobyl NPP.

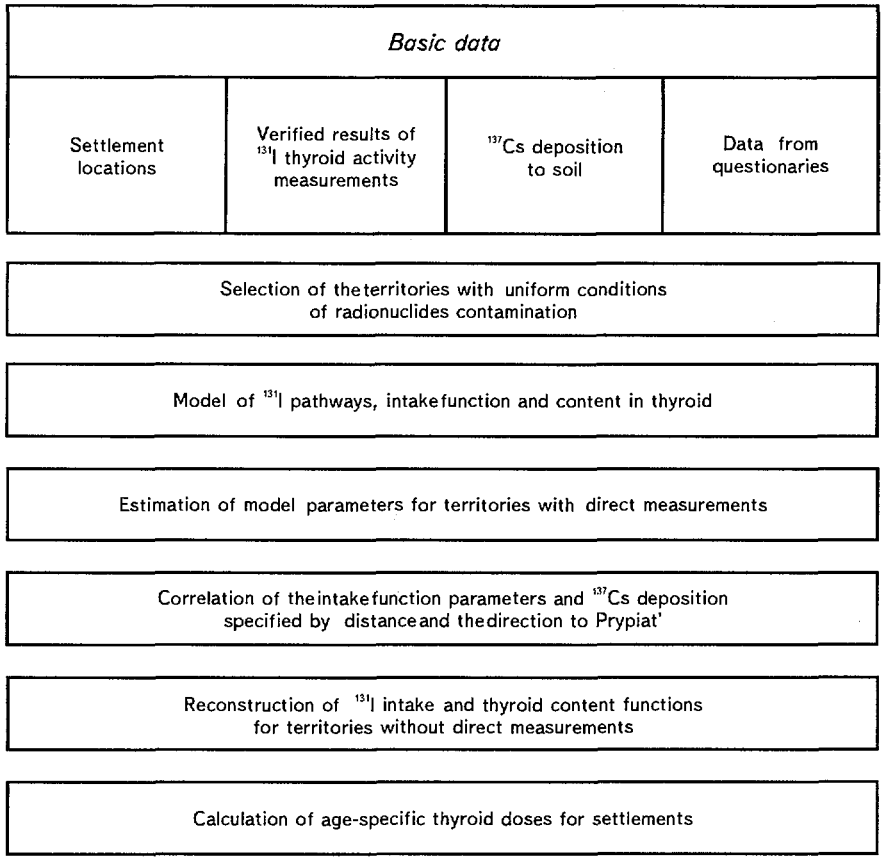

Fig.6. Scheme of the thyroid dose reconstruction for population of Vinnyts'ka and Cherkas'ka oblasts

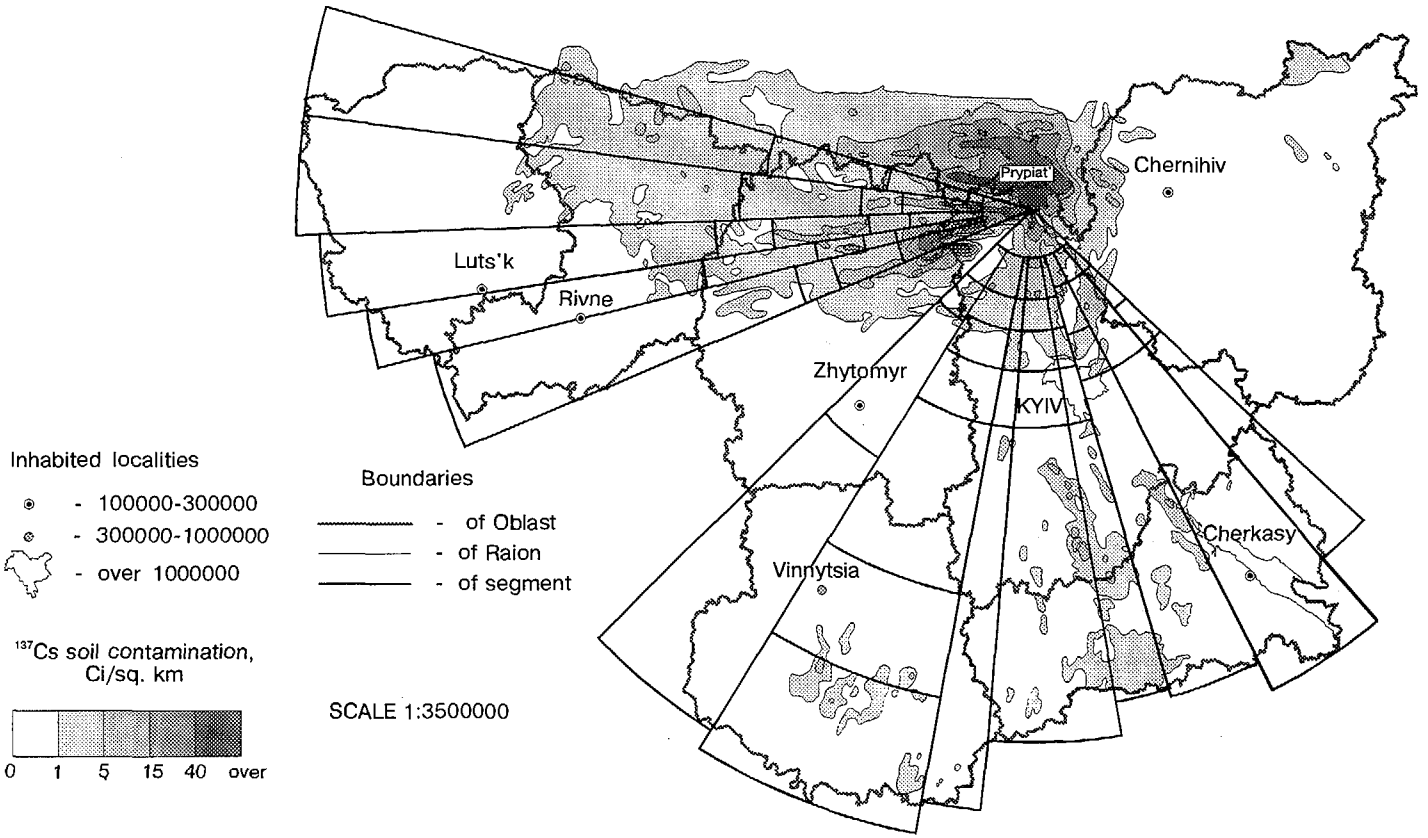

Fig.7. Sectors and segments on territory of northern part of Ukraine with the uniform ^{131}I thyroid intake function used for thyroid dose reconstruction

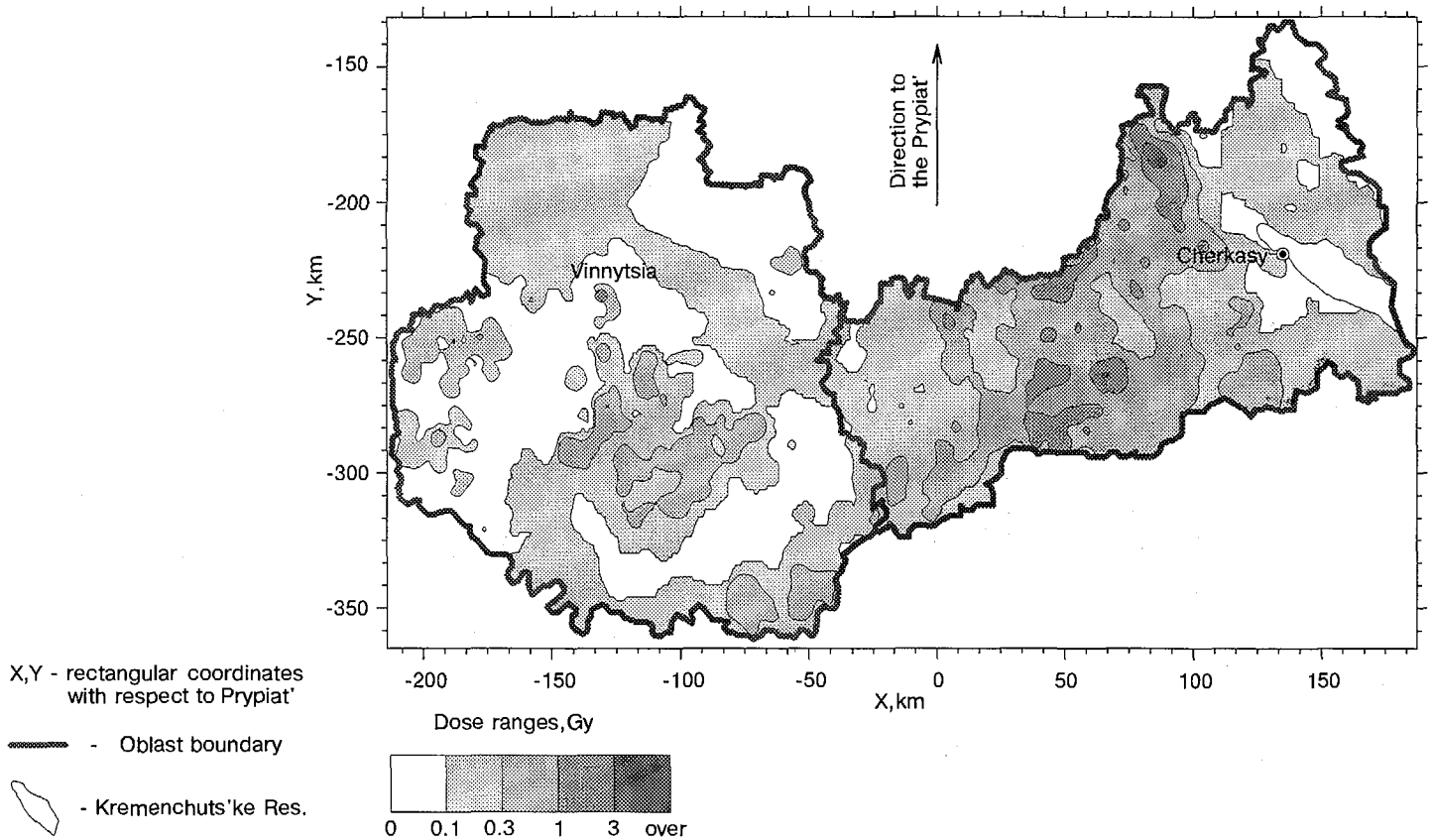

Fig.8. Thyroid doses from ^{131}I to children born between 1979 and 1982 in Vinnyts'ka and Cherkas'ka oblasts

Fig.7 shows the location of the sectors and the segments on the territory of the dose recovery. The relationship was found primarily for territory with direct measurements and then it was spread on other areas. The direct measurements performed in three raions of Vinnyts'ka oblast were used for estimation of the model parameters. Questionnaire data allowed to estimate milk and leafy vegetables age- and region-specific consumption rates used as parameters for the thyroid ^{131}I intake function model. Fig. 8 shows the spatial dose distribution for children born between 1979 and 1982 in Vinnyts'ka and Cherkas'ka oblasts. The results of the dose reconstruction reveal also the frequency thyroid dose distribution in different age groups of the population. Table 4 shows the dose distribution in seven age groups for the population of 5 oblasts listed above.

Table 4. Thyroid dose distribution in children of 5 oblasts*(%)

Age at the time	Dose range, cGy					
of the accident	0 – 4.9	5.0 – 9.9	10.0 - 29.9	30.0 – 99.9	100.0 -199.9	≥200
< 1	2.8	10.4	55.5	23.3	7.4	0.5
1-3	3.2	10.3	58.6	24.9	2.1	0.9
4-7	10.8	27.2	47.7	13.4	0.9	0.0
8-11	19.3	39.6	34.0	6.1	0.9	0.0
12-15	35.3	35.2	24.4	4.3	0.7	0.0
16-18	45.7	26.8	23.5	4.1	0.0	0.0
> 18	54.6	21.0	21.6	2.8	0.0	0.0

* – except 30-km zone and Kiyv city

4. CONCLUSIONS

By means of the thyroid dose reconstruction in Ukraine 6673 settlements with about 8,150,000 of inhabitants (2,223 thousand of children aged 0-18 in 1986) received the certificates with the average age-specific thyroid doses. Results of the thyroid dose recovery have revealed dose distributions in different age groups of the population. This allowed to estimate the values of age specific collective doses in different oblasts and raions. Results of reconstruction have also revealed spatial dose distribution. This allowed to seperate dose zones on the territory of Ukraine in according to average levels of thyroid exposure. Dose zones underlay a policy of the post-accident health care and social compensations. Other important applying of the reconstruction is radiation risk assessment of thyroid cancer in people exposed in childhood due to the Chernobyl accident.

Reference

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