RECALCULATION OF THYROID DOSES AFTER THE CHERNOBYL ACCIDENT IN AN IODINE DEFICIENT AREA

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Abstract

The thyroid doses were estimated in Poland shortly after the Chernobyl accident with assumption of stable iodine consumption for the reference man and areas with "standard" stable iodine consumption. These estimates are not representative for southern part of Poland which is known us the iodine deficient area. Therefore the thyroid doses were recalculated basing on the real and differentiated stable iodine intakes for people groups of different age without and with thyroid blockade after the accident.

1. INTRODUCTION

An assessment of thyroid dose after the Chernobyl catastrophe in Poland was performed by Zarnowiecki and Krajewski [1-3] using a dosimetric model of iodine metabolism in human body, developed by Johnson [4]. The assessments were performed under assumption that the consumption of stable iodine in Poland can be approximated by values used by Johnson for a Reference Man [5] i.e.. about 200 µg of iodine per day for a 70 kg adult man and correspondingly less for children e.g. 116 µg per day for 10 years' old children. The Johnson's model demonstrates that stable iodine intake significantly influences thyroid doses because it dilutes radioactive µg per day for 10 years' old children. The Johnson's model demonstrates that stable iodine intake significantly influences thyroid doses because it dilutes radioactive iodine in blood and in thyroid compartments thus the estimates made till now underestimated significantly the thyroid doses on some areas.

South part of Poland, heavily-contaminated after the Chernobyl accident, is known as an area of iodine deficiency. Well documented data obtained in the last years [6], clearly indicate that stable iodine consumption among schoolchildren and adults in Carpatien endemic is 2-3 times lower than those used in the previous estimates. This was the reason for recalculation of thyroid doses for inhabitants of this area basing on input data more reliable than those used in the first estimates.

The aim of this work was:

-to study the influence of stable iodine intake on thyroid doses basing on the recently obtained data on stable iodine intake and revised data on ^{131}-I contamination in the south-Poland taking as an example two administrative areas called voivodities i.e. Krakowskie and Nowosadeckie.

-to estimate the efficiency and the possible strategies of administration of stable iodine to block thyroid in the iodine deficient areas.

2. SOURCE DATA AND METHODS

Johnson's model and calculation procedure

The most important features of the model are well known therefore they are only listed in the present paper. More details are in the original paper [4] as well as in [l-3]. Johnson's model is a dosimetric, 5-compartment model which is designed to study the kinetics of iodine transfer to different organs and is oriented on calculation of the radiation dose absorbed in these organs. In practice, in the case of radioactive iodine uptake, only thyroid doses are of interest. iodine is assumed to come to blood from lungs or gastrial tract (see Fig.1). Then, it is partly transferred to a bladder and excreted with urine and partly absorbed in a thyroid. The rate of thyroid uptake is assumed to be proportional to the ratio of radioactive and stable iodine concentration in the inorganic compartment (blood). iodine that is incorporated in the thyroid is assumed to be mixed with iodine already present in the compartment. Then, iodine leaves thyroid with a given rate, inversely proportional to the thyroid mass.

During this study the calculations were performed by using a code MODELTAR, prepared by P. Krajewski [2]. The code enables to calculate, in a single run, thyroid dose for a given set of data such as time distribution of ^{131} -I activity intake, stable iodine intake and the subject characteristic (age and sex). When dosimetric calculations are performed, activity of radioiodine in thyroid, integrated over the time scale is recorded. Then, this integrated activity in the source organ is recalculated into

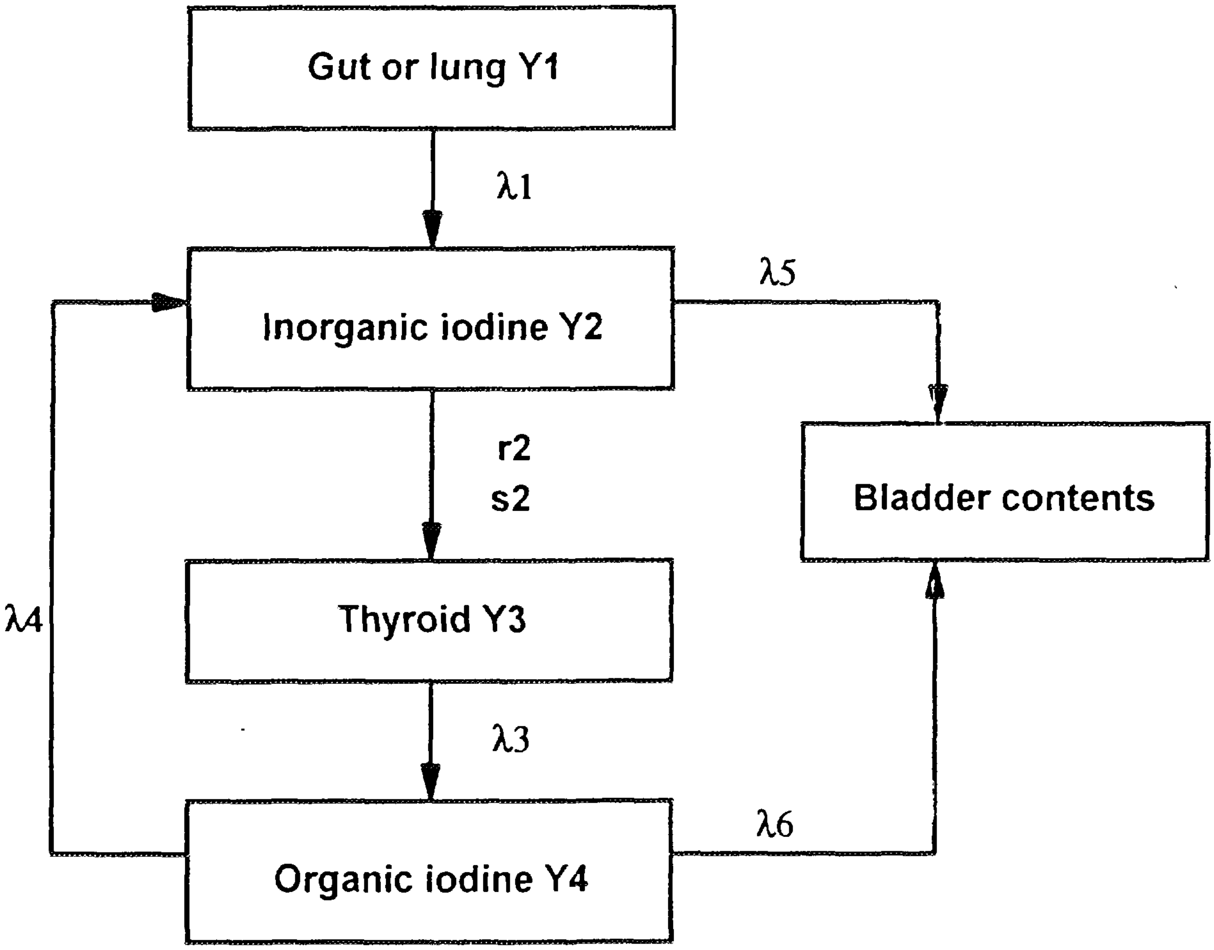

Fig. 1. Metabolic model for iodine in man

committed absorbed dose, (which numerically is equal to equivalent dose in the thyroid), with the use of dosimetric factor converting integrated activity in the source organ to dose [4].

Consumption of stable iodine

The intake of radioactive iodine to thyroid is dependent on the concentration of stable iodine in the blood. Therefore, consumption of stable iodine influences radioactive iodine intake and, in consequence, thyroid doses.

In 1993 a large, representative cohort of schoolchildren in south-eastern Poland in age from 6 to 13 year was investigated for iodine concentration in urine and the results were published by Rybakowa et all. [6]. In Figs. 2 and 3 the frequency distribution of concentration of iodine in urine for children in three age groups in Krakowskie and Nowosadeckie voivodities are given respectively. For the purpose of this study it was assumed that children excrete one litre of urine per day and that amounts of excreted and consumed iodine are equal. These data were used for

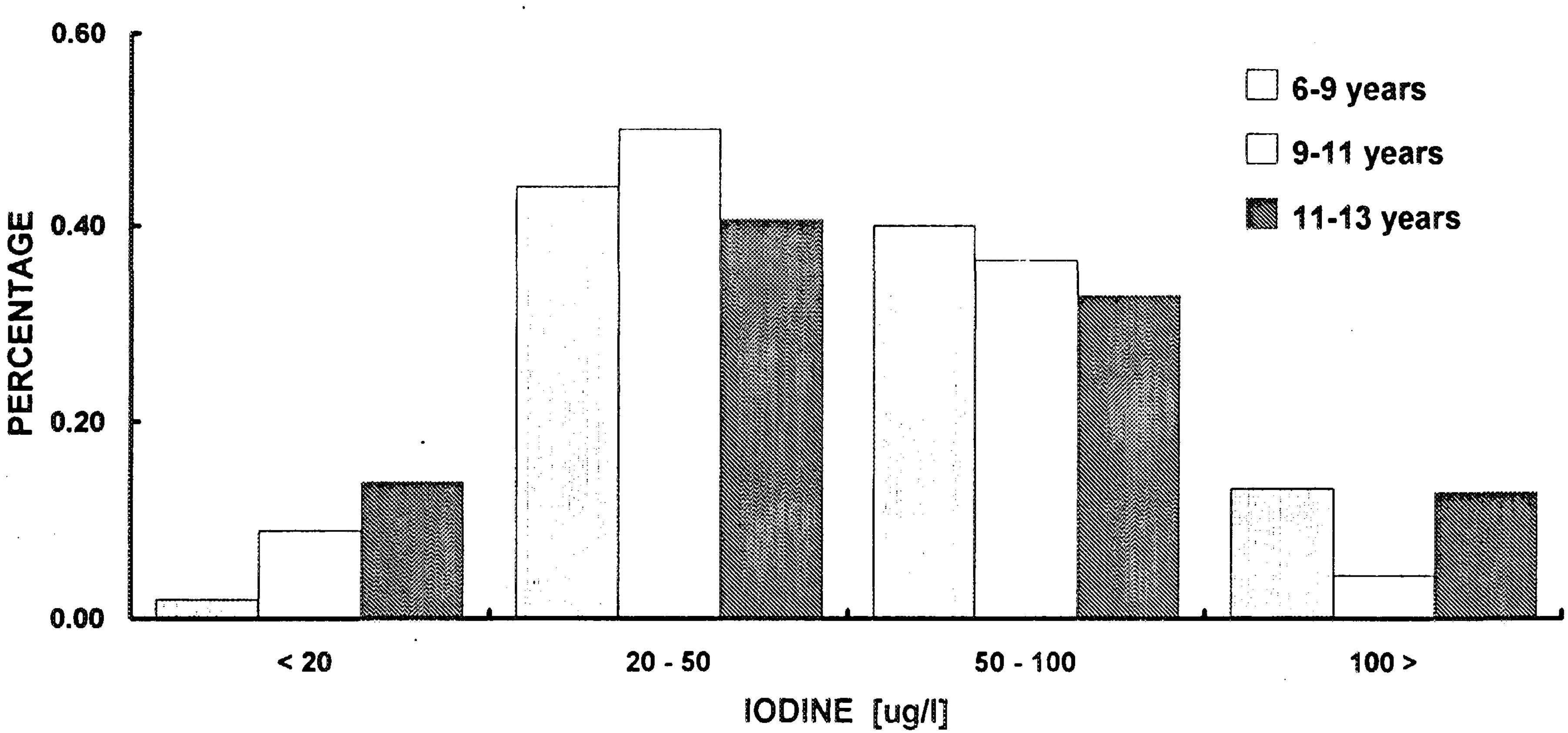

Fig.2. Frequency distribution of stable iodine in Krakowskie voivodity for children beween 6 and 9 years, between 9 and 11 years and between 11 and 13 years [6].

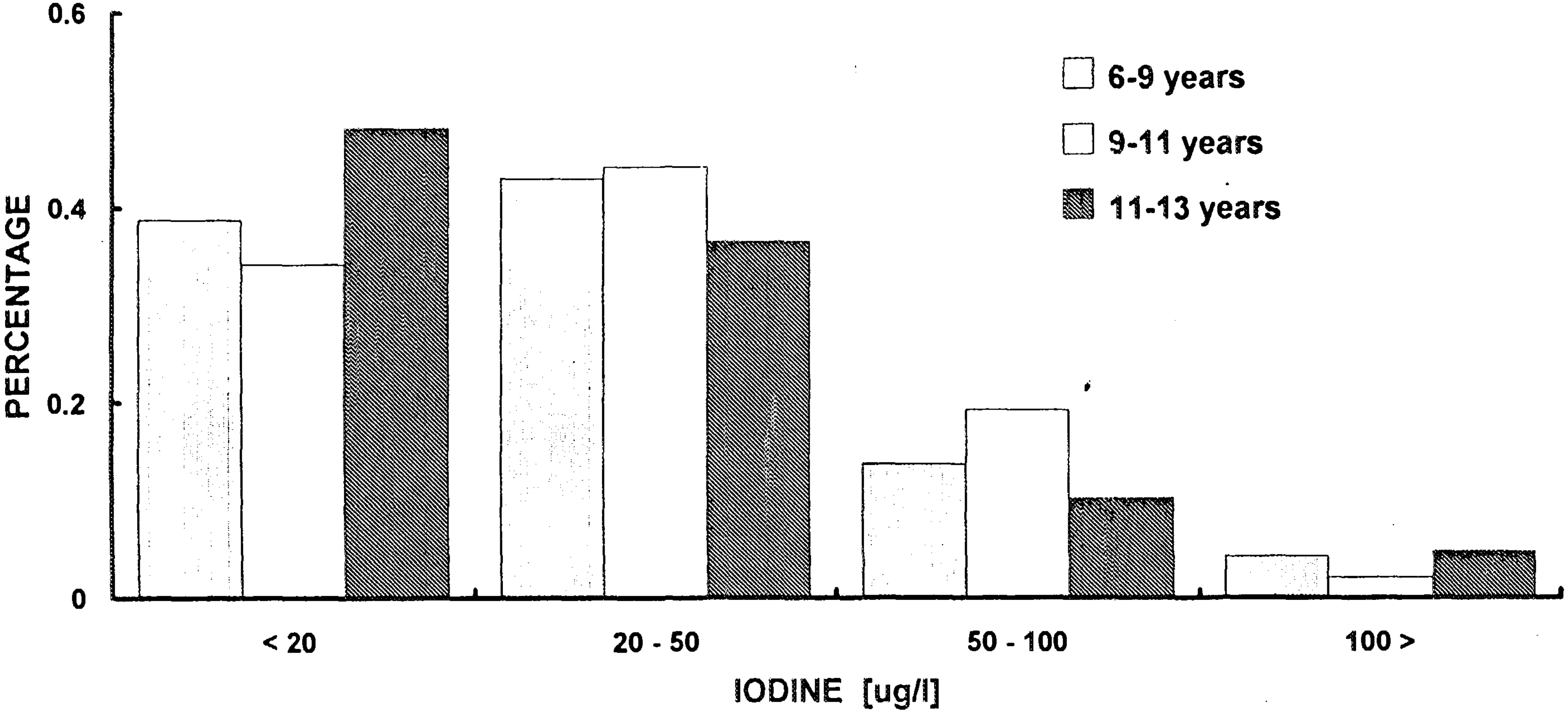

Fig.3. Frequency distribution of stable iodine in Nowosadeckie voivodity for children between 6 and 9 years, between 9 and 11 years and between 11 and 13 years [6].

children while for adults the daily iodine consumption was calculated on the base of a knowledge of dietary habits of population in Krakowskie and Nowosadeckie and of an average concentration of iodine in some basic food products [7, 8].

Intake of radioactive iodine

Thyroid doses, calculated in the present work, result principally due to ^{131}-I intake. The air which arrived from Chernobyl was contaminated also by other iodine isotopes mainly by ^{132}-I [9]. However, ^{132}-I contributed to thyroid dose more than one order of magnitude less than ^{131}-I and therefore was not taken into account in this study.

There are two main pathways of radioactive iodine intake i.e. inhalation and ingestion. The inhalation dominated during the first few days while the ingestion with milk, milk products, water and vegetables lasted practically to the end of May.

Inhalation

The amount of inhaled radioiodine was assumed to be dependent on time distribution of ^{131}-I activity in the air after the accident and on age-dependent breathing rate. For the ongoing calculations the results of measurements of ^{131}-I activity in air in Kraków obtained by Niewiadomski and Ryba (10) were used. The results, together with those used by Krajewski [3] are shown in Fig. 4. The diagram shows two activity waves, first one reached reached Kraków on April 29, a day later than Warszawa. Breathing rates taken from ICRP Report [5), which were used in the calculations, are shown in Tab.I. It was assumed in addition that 66"/a of ^{131}-I activity (inhalation class D), which entered the lungs during breathing, was transferred to the blood.

TABLE I. BREATHING RATE AND TOTAL ACTIVITY INTAKE DUE TO INHALATION FOR DIFFERENT AGE GROUPS [5].

Subject	Breathing rate m3/h	Activity [Bq]
Reference Man	0.98	3444
Reference Woman	0.88	3093
10 years' child	0.616	555
5 years' child	0.4	1406
1 year child	0.158	2165

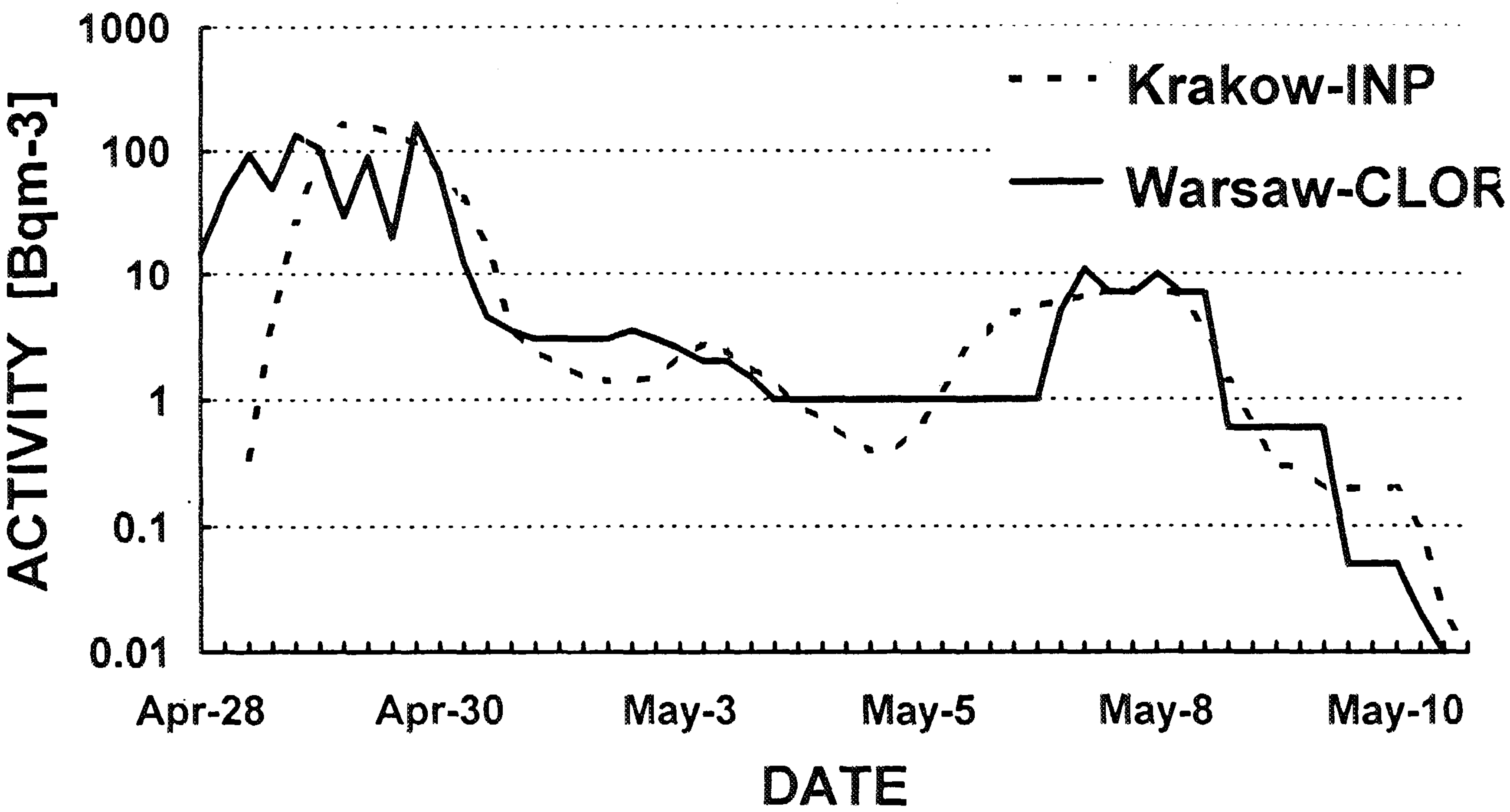

Fig.4. ^{131}-I activity in air measured in laboratories Kraków (Institute of Nuclear Physics, INP) [11] and Warsaw (Central Laboratory for Radiological Protection, COLOR) [2].

Ingestion

The dietary intake of radioiodine was mainly due to water, milk and milk products (cheese) consumption. The intake with contaminated vegetables could be neglected because, at the time of the accident, people were warned not to consume fresh vegetables. Changes in activity of radioiodine in water, as measured in rivers Wisla and Raba as well as in Kraków drinking water, are presented in Fig. 5 [9, 11]. Water in Wisla was assumed as representing drinking water for population of Krakowskie voivodity while this in Raba for Nowosadeckie voivodity. The data show an evident lower contamination in Raba river than in Wisla. Activity of ^{131}-I in drinking water in Kraków-town, measured in the AGH followed that in Wisla river therefore it was assumed that similar situation was as well on the territory of the whole voivodity as in Nowosadeckie.

Milk activity as measured by Cywicka-Jakiel et al [11] (Kraków-IFJ and Nowy Sacz) and Florkowski [9] (Krakow-AGH) is shown in Fig. 6. Milk in Kraków was measured in three large milk-factories, which collect milk from the distance of 10-20 km. The curves represent average values, because a short, heavy rain, which occurred on May 1 st, deposited differentiated local ^{131}-I contamination's, which caused the significant variations of milk activity.

The amounts of the most important diet components, which were used in the activity intake calculations, are presented in Tab.II.

TABLE II. THE AMOUNTS OF WATER AND FOOD WHICH WERE USED FOR THE CALCULATIONS OF ACTIVITY INTAKE [12].

Diet [kg]	Men	Women	1 year	5 years	10 years'
Milk	0.35	0.4	0.65	0.6	0.6
Water	2	2	1.0	1.5	2.0
Milk products	0.1	0.15	0.04	0.045	0.06

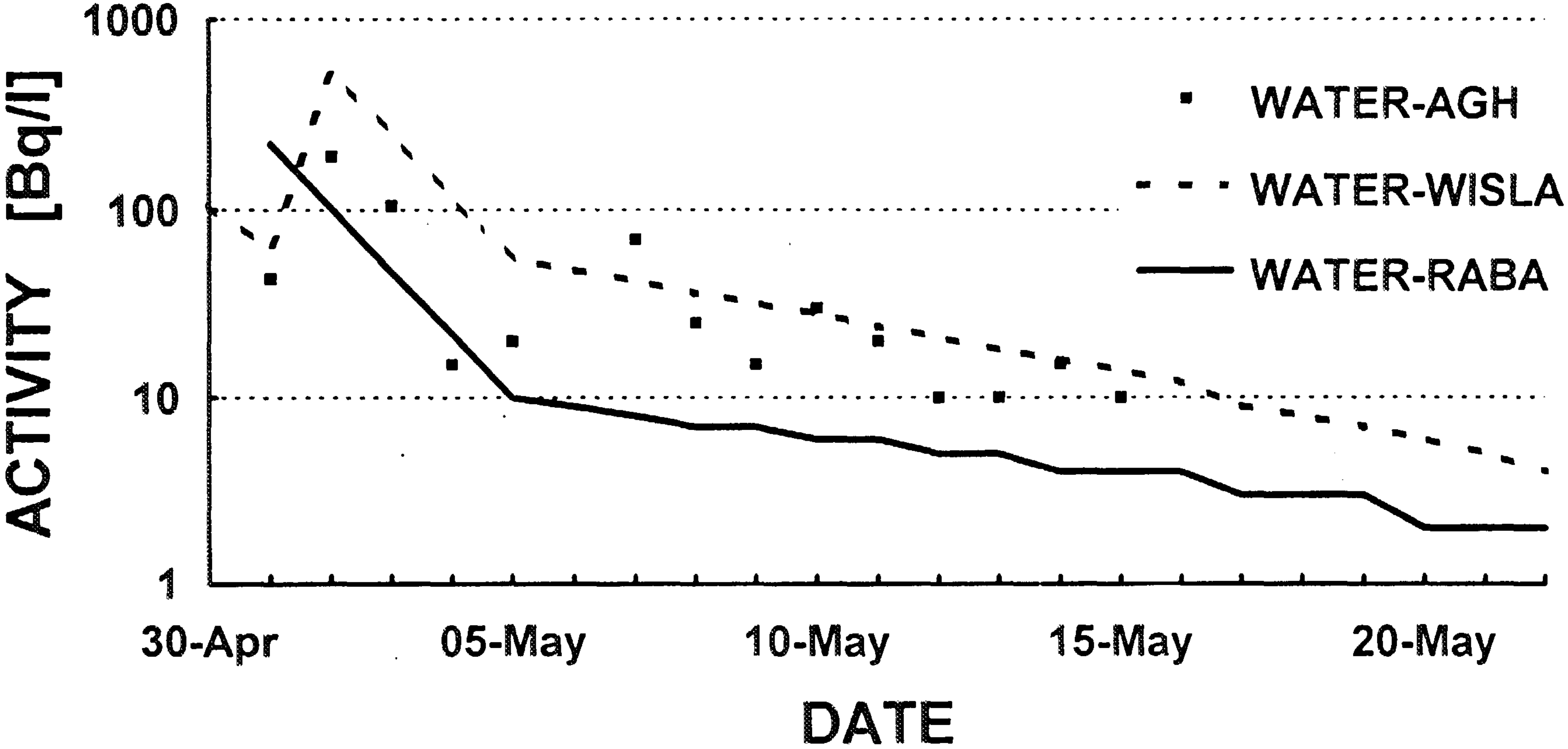

Fig.5. ^{131}-I activity in water in rivers supplying waterworks in voivodities Krakowskie (Wisła) and Nowosądeckie (Raba) as measured in the INP [11] and in drinking water in Kraków measured in the INT at the AGH [9].

Cumulative activity intake

^{131}-I cumulative amounts since April 30 to June 3 were calculated by integration over this period ^{131}-I activities by taken into account diet components listed in the Tab.II. and unit activities as presented in Figs. 5 and 6. For Krakowskie the data on water from Wisla and milk measured in IFJ were used whereas for Nowosadeckie the data on water from Raba and milk measured for this area. No difference for inhalation was assumed in both districts. The results of calculations are shown in Table III.

TABLE III. CUMULATIVE ^{131}-I INTAKE (INGESTION, INHALATION AND TOTAL) FOR DIFFERENT GROUPS OF PEOPLE IN THE PERIOD APRIL 30 - JUNE 3

INGESTION of ^{131}-I [Bq]

Voivodity	Men	Women	1 y.child	5 y.child	10 y.child
K	6920	7378	7191	7600	8504
N-S	2592	2739	2742	2845	3165

INHALATION of ^{131}- I [Bq]

Voivodity	Men	Women	1 y.child	5 y. child	10 y. child
K N-S	3444	3093	555	1406	2165

TOTAL ^{131}I INTAKE (Bq)

Voivodity	Men	Women	1y.child	5 y.child	10 y.child
K	10364	10471	7746	9006	10669
N-S	6036	5832	3297	4251	5330

Higher ^{131}-I intake for people living in Krakowskie than in Nowosadeckie (2. 6 times) was caused by difference in contamination of water and milk in Krakowskie due to the heavier rain on this area on May 1 st.

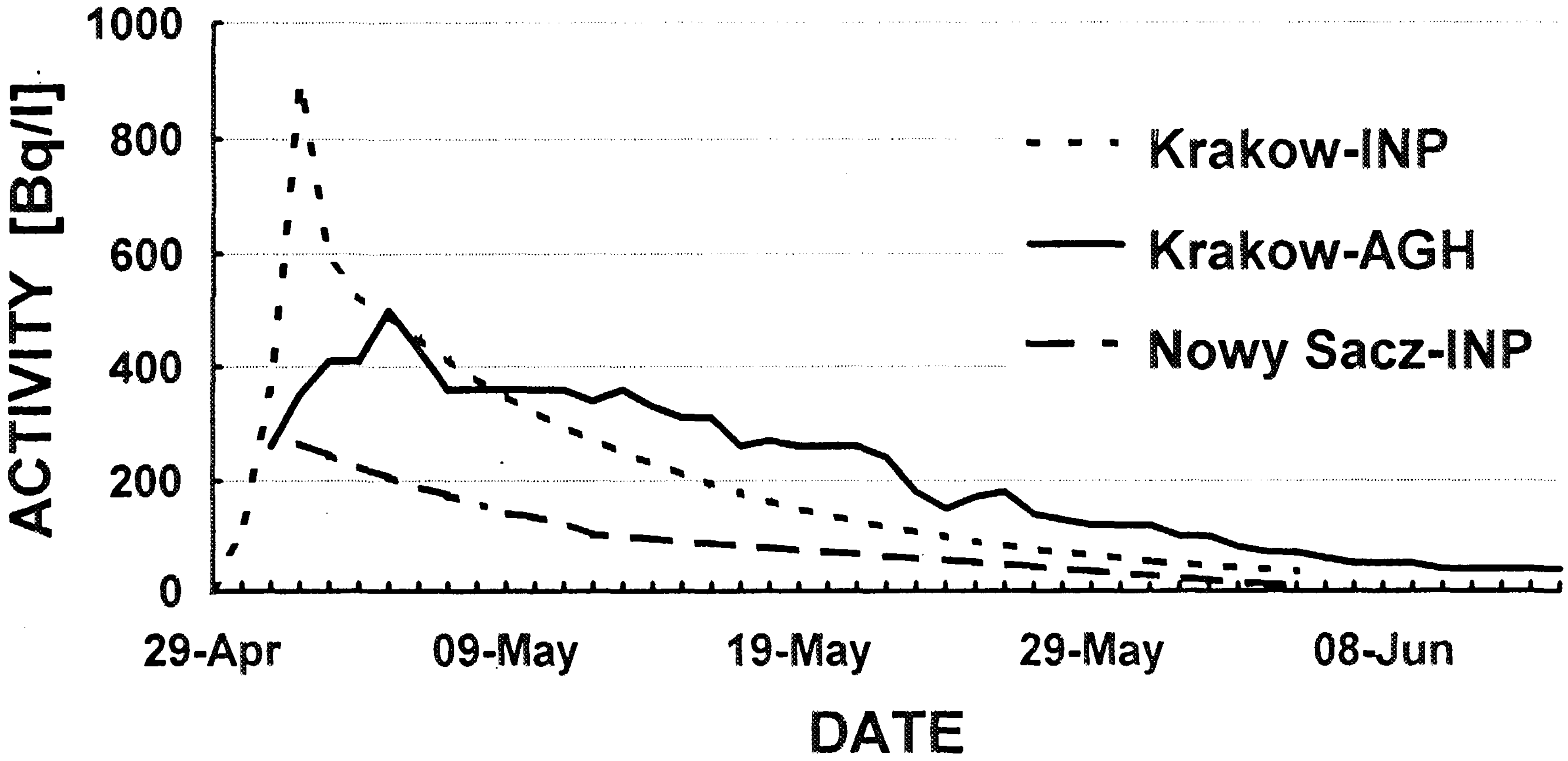

Fig.6. Activity in milk from diffrnt suppliers from Krakowskie and Nowosądeckie voivodities as mesaured in INP [11] and the INT at the AGH [9].

3. RESULTS AND DISCUSSLON

Changes of doses due to different stable iodine intake

Since one of the aims of this work was to estimate differences in thyroid dose due to various stable iodine intake before the radioiodine exposure therefore the population was divided into groups according to this parameter. Calculations for children were performed starting with calculations of thyroid doses for several single values of the stable iodine intake. Then the doses were weighted over the distribution presented in Fig. 2 to obtain the average thyroid dose for the given group of children. For the adults the estimates of average iodine consumption are only available Therefore, the calculations were performed for some discrete values of intake i.e. 35 (range25-50), 75(50-100), 150(100-200) and 200µg/day.

Committed thyroid doses for 10 years old children, calculated for several values of stable iodine intake are presented in Fig. 7. The calculated doses for the lowest intakes, about 20 µg/day amounted to 19.6 mSv in Nowosadeckie and 39 mSv in Krakowskie. The corresponding doses calculated for intake used by Johnson for 10 years old children (116 µg/day) are about 3 times lower i.e. 13.4 and 6.8 mSv respectively. Similar differences between doses for "standard" and really observed iodine consumption were also obtained for the other age-groups. E.g. for 11-13 years children in Nowosadeckie the assumption ofstable iodine consumption of 136 µg/day leads to 3.2 mSv dose. However, about 50% of these children consumed daily less than 20 µg of iodine thus the received doses were as high as 9.7 mSv.

Differences in doses between voivodities Krakowskie and Nowosadeckie are caused by two factors acting in opposite directions. The lower stable iodine intake in Nowosadeckie increases dose while the lower ^{131}-I contamination lowers them. While in Krakowskie only 9% of kids consume below 20 µg of iodine, in Nowosadeckie 34%, the weighted thyroid doses for Krakowskie (26 mSv) and Nowosadeckie (15 mSv) differ by the factor of 1.7.

The calculations performed for the Reference Man demonstrate a similar regularity (see Fig. 8). Thyroid doses for Krakowkie ranged from about 5 to 16 mSv. For the most probable stable iodine consumption between 50 and 100 µg/day, the thyroid dose for this area was 6.5 mSv.

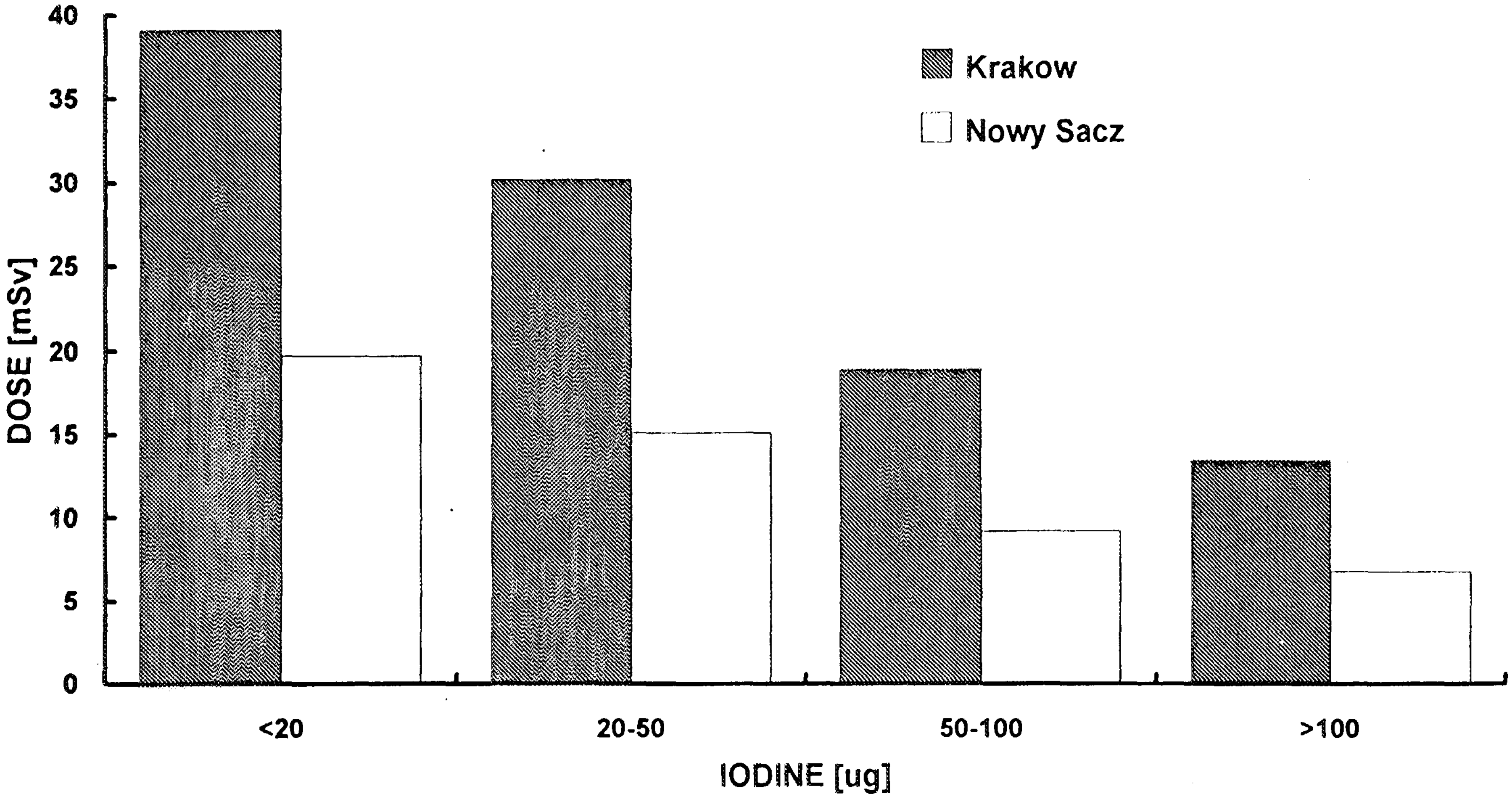

Fig.7. Committed thyroid dose for children of 10 years old inKraków and Nowy Sącz in dependence on stable iodine intake.

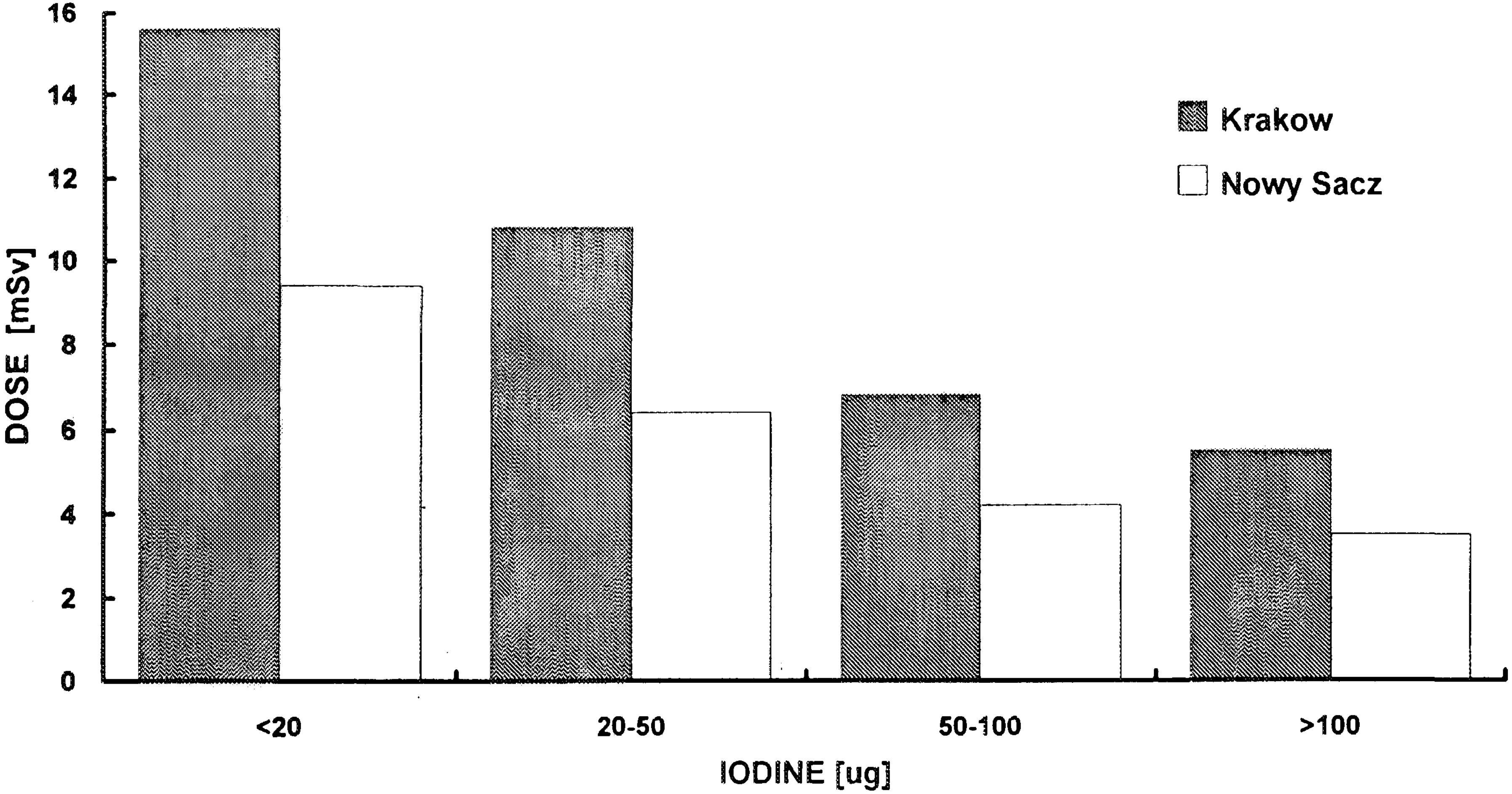

Fig.8. Committed thyroid dose for reference man in Kraków and Nowy Sącz in depedence on stable iodine intake.

The variation of thyroid dose is discussed in this paper with regard to stable iodine consumption using average radioiodine intake for given area. It is worth to mention that the variations of dose due to differences in ^{131}-I intakes were surely much higher. The reason for that are local (not recorded) contaminations due to the rain of different intensity and variations in the diet.

Effects of stable iodine administration (blocked)

One of the discussed problems during the iodine phase of Chernobyl catastrophe was usefulness and strategy of administration of prophylactic doses of stable iodine. This action was started in Poland on April, 29, 1986 in eleven most contaminated districts, also in Krakowkie and Nowosadeckie. Stable iodine doses, in amount of 15 to 60 mg were recommended and administered to infants and children up to 16 years.

The result of this action i.e. the remaining dose fraction after administration of a single dose of 15 mg iodine to 1 year old child, in the function of administration day is presented in Fig. 9. It can be seen from the figure that the action had limited effect and that the highest dose reduction (68%) could be obtained if the action would start on May 2nd. The reason for that is that the maximum intake of ^{131}-I occurred in south-Poland after a heavy rain on May 1 st which resulted in a strong milk contamination during the next days. These high levels of milk contamination were significant over the whole May. A single prophylactic dose of iodine is however effective for about one week only. While the most ^{131}-I intake happened later, mainly from milk and water consumption, single prophylatic iodine doses had little impact on decreasing children thyroid doses.

The amount of stable iodine is also not a critical parameter for dose reduction, as can be seen in Fig. 10. Of course, the situation could be quite different if the ^{131}-I intake by ingestion is reduced e.g. by introducing milk powder on the market. Then, thyroid blockade is much more effective [3] because the most serious inhalation intakes lasts about one week. It is difficult to predict a single, best day for a thyroid blockade with a high iodine dose. It would be better to administer (from the radiation protection point of view because medical point of view can be different) low-doses of iodine eg. 1 mg per day, but over a period of a month.

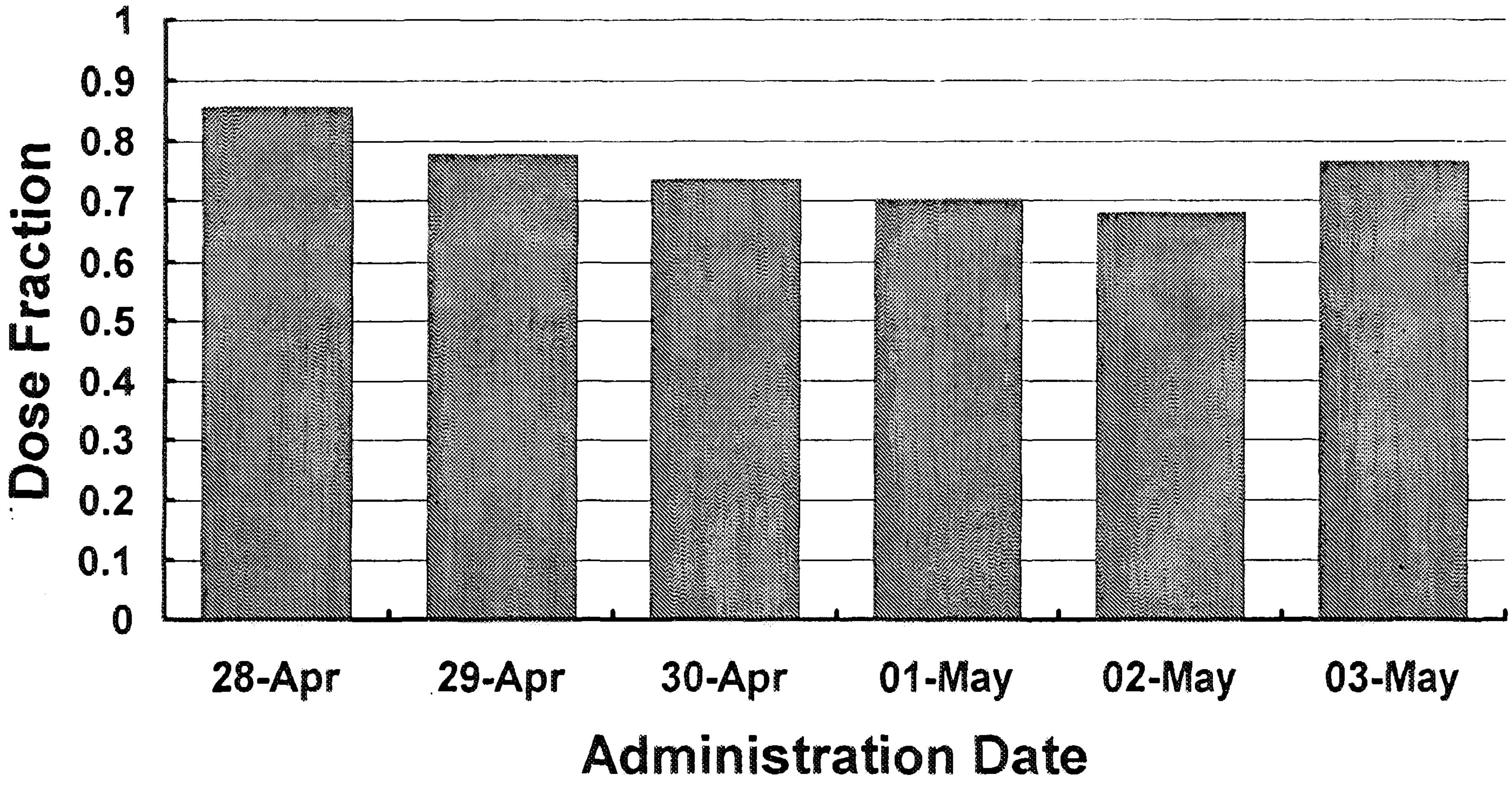

Fig.9. Effect of thyroid blockade: 1 year child, by 15mg stable iodine administered on different days, daily iodine intake 20 μg.

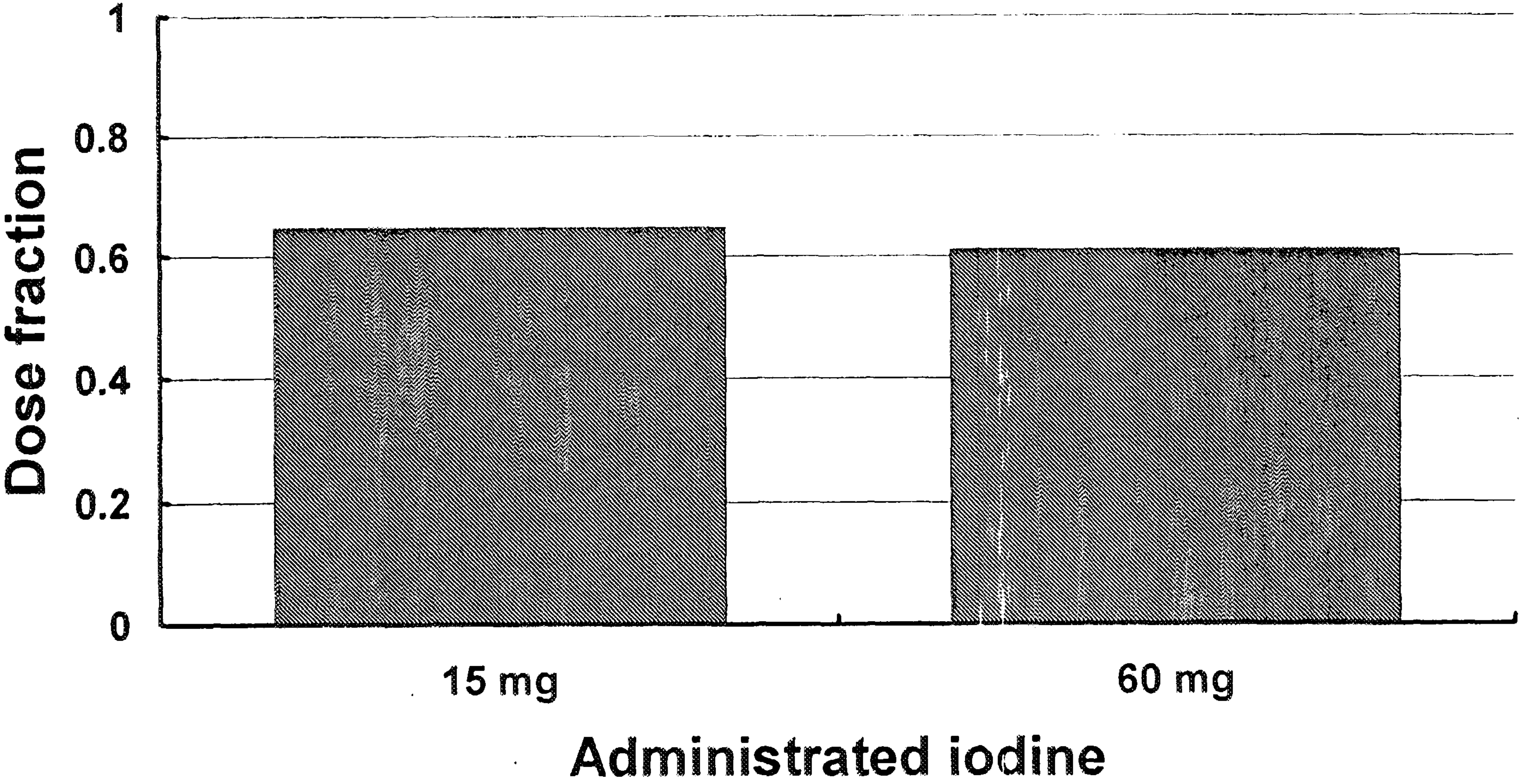

Fig.10. Effect of thyroid blockade: 1 year child, 15 and 60 mg of stable iodine administered on May 2nd.

CONCLUSIONS

It was demonstrated that thyroid doses after accidental ^{131}-I intake are seriously dependent on the state of saturation of thyroid by stable iodine. The stable iodine concentration is low on some areas where a lack of this element in water and food occurs. An example of such area is the territory of south Poland. Calculations for inhabitants of this territory, based on the Johnson's of iodine metabolism in human body has shown that for 10 years old children who consume daily 20 μg thyroid dose is three times higher that the dose for children with "standard" 116 μg intake and with the same ^{131}-I consumption with air, food and water.

The estimates of the optimal day of thyroid blockade by administration of stable iodine to children has shown that this blockade is effective for one week only, thus the day of administration should be chosen in dependence of anticipated situation of radioiodine supply. Since this is rather difficult it often would be better to administer low doses of stable iodine e.g. I mg per day over the period of one month instead of the single high dose. As far as situation in south Poland after the Chernobyl catastrophe is concerned it was found that the amount of the prophylactic stable iodine was not a critical parameter for thyroid dose reduction thus the lower dose could be recommended as this which results lower medical complications in the future life of the person who was the subject of this type of recovery operation.

REFERENCES

[1] K. Zarnowiecki, An Analysis of Radionctive Conlamination and Radiation Hazard in Poland after theChernobyl Accident, CLORReport 120/D, (I988), (in Polish).

[2] K. Zarnowiecki and P. Krajewski, An Assessment of Committed Dose Equivalent in Thyroidfor Population of Poland in Result ofl 131 Intuke afler tl:e Chernobyl Accident, CLOR Report (1987), (in Polish).

[3] P. Krajewski, Effect of Stable Iodine Administration on Reduction of Thyroid Conrent of I-131 for Warsaw Population after the Chernobyl Accident, Internat. Symp. on Recovery Operabon in the Event of Nuclear Accident or Radiological Emergency, Vienna, Austria, 6-10 November 1989. IAEA-SM-316/19. [4]. J. R., Johnson, Radioiodine Dosimetry, J. Radioanal. Chem. 65. pp 223-238, (I981).

[4] Report ofthe Task Group on Reference Man, ICRP Publication 23, Pergamon Press (1975).

[5] M. Rybakowa, D. Tylek, R. Ratajczak, A. Anton, M. Skalski, E. Przybylik--Mazurek, B. Huszno, F. Golkowski, A. Tarnawski and Z. Szybinski, Goiter Incidnce and Urinary Iodine Excretion in Children of Age group 6-13 Years Living in South Eastern Poland, Endokrynologia Polska, 44, pp. 249-258, (1993).

[6] Dłużniewska, private communication, 1990.

[7] A. Szczygiel, J. Piekarska, B. Horszczaruk, Tables ofcomposition and alimentary values of food products. PZWL eds, Warszawa, 1975, (in Polish).

[8] T. Florkowski, T. J. Grabczak, T. Kuc, K. Rózanski, Tracing the Radioactive Cloud in Kraków after the Chernobyl Nuclear Accident. Institute of Nuclear Technology, Report No. 215/I, Kraków (1987).

[9] T. Niewiadomski and E. Ryba. Report on Investigations ofsome Effects of ChernobylAccident in Krakáw, Raport No 1329/8, Institute of Nuclear Physics, Kraków (1986) (in Polish).

[10] T. Cywicka-Jakiel , P. Grychowski, I. Hajdas, M. Jasinska, L. Kolaczkowski J.Loskiewicz, Z. Mazgaj, J. Mikulski, E. Ochab, Radioactivity Measurements in Krakow Sorroundings in the afternath of Chrernobyl Reactor Accidenr, Institute of Nuclear Physics, Raport No. 1407/AP, (1988)

[11] E. Araszkiewicz, private communication.