IAEA-TECDOC-958

Dosimetric and biomedical studies conducted in Cuba of children from areas of the former USSR affected by the radiological consequences of the Chernobyl accident

INTERNATIONAL ATOMIC ENERGY AGENCY

The IAEA does not normally maintain stocks of reports in this series. However, microfiche copies of these reports can be obtained from

INIS Clearinghouse
International Atomic Energy Agency
Wagramerstrasse 5
P.O. Box 100
A-1400 Vienna, Austria

Orders should be accompanied by prepayment of Austrian Schillings 100,— in the form of a cheque or in the form of IAEA microfiche service coupons which may be ordered separately from the INIS Clearinghouse.

The originating Section of this publication in the IAEA was:

Safety Co-ordination Section
International Atomic Energy Agency
Wagramerstrasse 5
P.O. Box 100
A-1400 Vienna, Austria

DOSIMETRIC AND BIOMEDICAL STUDIES CONDUCTED IN CUBA
OF CHILDREN FROM AREAS OF THE FORMER USSR
AFFECTED BY THE RADIOLOGICAL CONSEQUENCES OF THE
CHERNOBYL ACCIDENT
IAEA, VIENNA, 1997
IAEA-TECDOC-958
ISSN 1011-4289

Printed by the IAEA in Austria
August 1997

FOREWORD

As a result of the accident at Chernobyl nuclear power plant in April 1986, large areas of Belarus, the Russian Federation and Ukraine were contaminated by radioactive fallout. The unprecedented environmental consequences gave rise to widespread concern and debate about possible effects on the health of people in the affected territories.

At the end of the 1980s, social organizations of the USSR requested co-operation from the world's scientific community in providing medical care for people from the areas affected by the accident. In March 1990 the Government of Cuba, in response to this appeal, initiated a comprehensive medical care programme to treat children from these areas. Dosimetric and biomedical studies were conducted by Cuban scientists, including: measurement of body content of caesium-137; estimation of internal, external, thyroid and total doses; and investigation of general health and of haematological, biochemical and cytogenetic indicators.

Several conferences have been convened by the international scientific community to discuss the findings of various projects that have focused on the Chernobyl accident and its aftermath. As part of these international efforts, the Cuban Ministry of Science, Technology and Environment, through its Centre for Radiation Protection and Hygiene, and with the co-operation of the IAEA, organized a Seminar on Cuban Studies of Children from Areas Affected by the Chernobyl Accident. At the Seminar, which was held on 14–17 November 1995 in Havana, Cuban experts presented information obtained from the dosimetric and biomedical investigations of children under the comprehensive medical care programme.

At the request of the IAEA, an international panel of experts attended the Seminar to conduct an independent peer review of the Cuban study, in particular the results of the dosimetric evaluation of the children. The panel of experts discussed with the Cuban authors the information presented at the Seminar and made a number of recommendations, in particular in relation to methods of estimation of doses. The present TECDOC includes the final Cuban report on the study, as revised and clarified in the light of the panel's recommendations. The panel of experts also prepared a statement of the peer review's main conclusions and recommendations, which is presented in this TECDOC before the Cuban report.

In April 1996, the IAEA held a Conference on One Decade after Chernobyl: Summing up the Consequences of the Accident. Two major objectives of the Conference were to agree on proven scientific facts and to clarify interpretations and prognoses in order to dispel confusion. The conclusions of several international and national projects, including the dosimetric and biomedical studies conducted in Cuba, were reported, documented and discussed at this gathering and integrated into a broad international consensus.

It is expected that the information presented here will contribute to an accurate evaluation of the health effects of the Chernobyl accident, and thereby help to consolidate knowledge and broaden understanding of the consequences of the accident, and permit the countries affected by them to develop well informed and balanced policies for their alleviation.

EDITORIAL NOTE

CONTENTS

PEER REVIEW OF CUBAN STUDIES OF CHILDREN FROM AREAS AFFECTED BY THE CHERNOBYL ACCIDENT

1. TERMS OF REFERENCE

The IAEA requested an International Panel of Experts (1) to assess the information presented by Cuba at the Seminar, in particular the results obtained from the dosimetric evaluation of children from Ukraine, Belarus and Russia, (2) to peer review the information provided, and (3) to prepare a consolidated statement highlighting the major conclusions and recommendations.

2. ORGANIZATION

The Panel of Experts was composed of:

- Nénot, J.C.(Chairman) — Institut de protection et de sûreté nucléaire, France
- Inkret, W.C. — Los Alamos National Laboratory, USA
- Kerekes, A. — Nat. Res. Institute for Radiobiology and Radiohygiene, Hungary
- Seyama, T. — Radiation Effects Research Foundation, Japan
- Oliveira, A.R. — Industrias Nucleares do Brasil, Brazil
- González, A.J. — International Atomic Energy Agency

J.C. Nénot presented the main conclusions of the Panel to the Cuban authors at the end of the Seminar.

3. MAIN TECHNICAL AND SCIENTIFIC ISSUES

The Seminar consisted of the presentation of the work undertaken by the Centre for Radiation Protection and Hygiene (CPHR) since 1990, under the request of social organizations of the former USSR, addressed to the Government of Cuba. The CPHR started this operation in March 1990, in collaboration with some departments of local hospitals.

The Cuban Report gathers the experience gained from the dosimetric and medical assessments made on a total of more than 4500 and 3000 children, respectively. The Panel of Experts had the opportunity to discuss all presented data with the Cuban specialists, especially those who presented their results at the Seminar.

These specialists reacted favourably to the summary of the Conclusions drawn up by the Panel of Experts and presented to the Cuban experts at the end of the Seminar. The Panel of Experts was acknowledged during the closing session by the Minister of Science and Technology of Cuba.

In its Review, the Panel of Experts does not bear any judgement on the overall benefit of this action. However, it recognizes that the benefit includes health gains for diseased and non-diseased children and the acquisition of valuable information.

The main conclusions of the Panel of Experts deal separately with the dosimetric assessments and the biomedical studies.

3.1. Dosimetry

Because of the different methods used in assessing the doses related to caesium, strontium and iodine, these three radionuclides have been considered separately by the Panel of Experts.

Internal dose from caesium

The body content of caesium was measured by whole body counting. The Panel of Experts was impressed by the quantity and quality of the data provided by the Cuban specialists. This set of data is probably unique in the world, as it covers more than 4500 children whose body contents were measured by a single team of physicists using the same equipment. Therefore, this data can be considered as representative, homogeneous and traceable, which is probably not the case for those available in the Republics of Ukraine and Belarus and the Russian Federation. The Panel of Experts has deemed this data to be the most reliable on this topic among all the measurements taken since 1986.

Some questions have been raised concerning the *calibration*, such as the need for potassium-40 and calcium in the various phantoms used to represent the various ages of the children, from 5 years to adulthood. The Specific Effective Energy correction formula for children used by the Cuban specialists introduces a slight underestimation (15% to 30% for young children), compared with the current values accepted by ICRP.

Some concern is related to the dose assessment from the continuous intake of caesium. Between the times of their departure from their countries and that of whole body counting in Cuba, varying periods of time elapsed, during which normal decorporation of caesium occurred without additional intake. As the biological half-life of caesium is relatively short in children (around 2 weeks at the age of one year and less than 2 months at 10 years), this parameter might have introduced a bias in the dose assessment. However, it seems that the recorded data may allow for corrections.

The Cuban specialists noted a possible trend of increasing measured body burden with increasing ground contamination in contaminated territories. As some mapping of the ground deposits originates from the first evaluation done in the former USSR, and its reliability is unknown, this result may be questioned. The Panel of Experts regrets that samples from the direct environment of each child (soil, foodstuffs and water) were not sent to Cuba along with the children. Had this step been taken, the relationship between environmental contaminations and children body contents could have been evaluated with lower uncertainty.

External dose from caesium

The external doses received by the children were derived from the same mapping; the Panel of Experts recognizes that these data were the only ones available when the Cuban study started, but raises the question of whether they are representative. As more reliable data have been published since then, a reassessment might be undertaken.

Another question arises with regard to the decay of ground deposits with time. The value chosen to represent this decay is questionable, due to the combined effect of the environmental conditions and the physical decay of caesium.

Internal dose from strontium

The assessment of the dose from strontium cannot be compared with that from caesium, because:

(i) no direct measurement being possible, the strontium dose was evaluated by using maps of ground contamination of the same source as those used for caesium;

(ii) the strontium dose was evaluated on the basis of a hypothetical direct correlation between strontium present in the environment and strontium intake by the population; and

(iii) the parameters used to illustrate the transfer of strontium from environment to man are derived from UNSCEAR and are based on weapon tests fallout; they probably do not apply to strontium generated by the Chernobyl accident.

Dose from iodine

The above reservations (i) and (ii) concerning strontium apply to iodine as well as to the estimated contributions of various pathways (inhalation and ingestion mainly) which are purely hypothetical. In fact, the reservations are especially applicable to iodine, as the contribution of iodine to the total dose is high. In addition, the correlation between iodine deposition and caesium deposition remains to be proved. A greater accuracy in expressing the iodine dose would have been useful for discussing the attributability of the increasing rate of thyroid cancers which is reported in some areas in Ukraine, Belarus and Russia since 1990-1991.

Assessment of the total dose

The total committed individual dose is a product of the addition of the external dose from caesium and the internal dose from caesium, strontium and iodine; the weight of uncertainties in expressing each component varies widely depending on the pathway and radionuclide selected. Finally, the total dose expressed conveys a misleading impression of accuracy in view of the substantial uncertainties in the evaluation of the external dose from caesium and of the internal dose from various radionuclides.

For this reason, the Panel of Experts, while recognizing the undeniable value of the caesium measurements and derived doses, recommends that:

(i) A clear distinction be made between robust data (such as those derived from in vivo measurements of caesium) and those obtained through modelling; and the degree of speculation for assessing exposures be stated.

(ii) The Report describe all calculations, including detailed statistical means and bio-mathematical models, and indicate which confidence intervals it has chosen.

3.2. Biomedical studies

The common point of all the biological and medical studies presented is their negative aspects, i.e. either the findings are completely normal or, when significant differences have been found between the children from affected areas and controls, these differences cannot be attributed to radiation and probably not even to the catastrophic situation due to the accident.

The Panel of Experts felt that the Cuban Report does not point out the accuracy of the various results expressed. This heterogeneity covers a very large range, from very precise findings such as hormone dosages for expressing the thyroid function to the assessment of possible health effects, such as the expected number of cancers among the children by multiplying the assessed collective dose by the ICRP risk factors. The resulting number of 1.5 expected fatal cancers among 4501 children and of 0.22 expected fatal thyroid cancers gives a misleading impression of exactness.

In addition, the number of thyroid hyperplasias (more than 60% of the children) seems very high. Although there could have been a selection bias to account for this high incidence of thyroid hyperplasia, it is difficult to relate it only to the selection criteria. As it is now clear that the incidence of childhood thyroid cancer is increasing in the areas contaminated by the Chernobyl accident, this question should be clarified. Therefore, the Panel of Experts recommends that a special effort should be made for improving the methods (such as ultrasound detection) and criteria for the diagnosis of thyroid diseases.

The biological studies conducted are useful at many levels: they are of benefit to the children themselves and to scientific knowledge in general. Yet while the detection of several diseases and their subsequent treatment improved the health conditions of the children, they failed to generate any valuable information concerning radiation hygiene or more generally, radiobiology or radiopathology. This action has to be acknowledged for its humanitarian dimension and its undoubtedly beneficial effect on the children who spent a limited period of time in Cuba. By contrast, the cytogenetic studies performed on 69 children were neither medically nor scientifically well founded, as the estimated doses were well below the detection level in relation to the number of cells scored.

4. GENERAL CONCLUSIONS

The technical value of the Cuban data on caesium, monitored between 1990 and 1995 on a large, coherent and homogeneous group of children from areas contaminated by the Chernobyl accident, should be recognized by the scientific organizations involved in the assessment of the accident's consequences. These results are probably the most reliable data on a large population which can allow to evaluate total intake and consequently, the internal exposure due to caesium-137. Moreover, the data can be traced and is thus open to calculation and modelling modifications, as well as additional statistics.

The evaluation of the other component of the total dose, i.e. the external dose from caesium and internal doses from strontium and iodine, are more speculative. As the potential health effects resulting from the accident are directly related to the total dose, some efforts should be made to refine data on these other components which, in some cases, might be major contributors to total dose. Whatever the case may be, a determination of the total dose cannot be expected with the same level of accuracy as the internal dose from caesium.

Based upon the preceding considerations, the Panel of Experts recommends that, in general, a clear distinction be made between robust data on the one hand, and approximations, estimations, comparative modelling, etc., on the other. At each step, the degree of certainty, the methodology and details of calculations should be stated and discussed. To achieve this, the Cuban scientists and other national and/or international bodies should be encouraged to co-operate, in particular for the completion or replacement of some sets of their data which need to be strengthened.

CUBAN STUDIES OF CHILDREN FROM AREAS AFFECTED BY THE CHERNOBYL ACCIDENT

SUMMARY

Children from areas affected by the Chernobyl accident have been receiving medical care in Cuba since 1990. The dosimetric and biomedical studies made include: measurement of ^{137}Cs body content; internal, external, thyroid and total dose estimation; evaluation of the overall health condition and behaviour of haematological, endocrinological, biochemical and cytogenetic indicators.

Measurements of body activity and dose estimation have been performed on altogether 4506 children. Of this total, 69.3% of the children were from the Ukraine, 22.5% from Russia and 8.1% from Belarus. Assessments of overall health conditions, haematological and thyroid indicators have been made covering 3016 children from 421 Ukrainian townships, taking into account the body measurements of ^{137}Cs and the surface contamination of the locations where the children come from. The biochemical indicator used (nucleic acid concentration in leucocytes) was assessed in five groups comprising some 445 children from areas where the level of surface contamination varied. Chromosome and micronuclei aberration rates were established in 28 children evacuated from Pripyat, 21 living in Kiev and 20 in Ovruch.

Specific body activity fluctuated between 1.5-565 Bq/kg (90% of children with values under 20 Bq/kg). For the period covering the study year, the estimated doses were as follows: external dose, <1-30 mSv (90% of children with values under 2 mSv); internal dose (^{137}Cs), <1-8.5 mSv; in the thyroid gland, 0-2 Gy (44 % of the children with values under 40 mGy); total dose, <1-85 mSv (80% of the children with values under 5 mSv). The most frequent diseases were endocrine-metabolic (mainly thyroid hyperplasia 1A and 1B), haematological (mainly non-specific chronic adenitis) and respiratory. Fifteen per cent (15%) of all cases had haemoglobin levels below values considered normal. Lymphocitosis was present in 59% of all cases, linked to parasitic infectious diseases. Seventeen per cent (17%) had a normal TSH, accompanied by a high T4. Thyroid hyperplasia augmented as a function of the internal contamination by ^{137}Cs and the surface contamination of the territories where the children were located at the time of the accident. All other indicators examined showed no variations between groups. Nucleic acid concentration did not decrease between groups. Dicentric and micronuclei rates per one hundred cells were 0.02 and 0.56 in Pripyat, 0.04 and 0.6 in Kiev and 0.03 and 0.87 in Ovruch. All individual rates were normal.

1. INTRODUCTION

As a result of the accident of the Chernobyl nuclear power plant, large territories of Belarus, Ukraine and the Russian Federation were contaminated, thus creating an unprecedented situation in the environment and many expectations and debates concerning its effects on the health of the people within the affected territories and neighbouring areas.

By the end of the 1980s, certain social organizations of the former Soviet Union requested effective co-operation from the world scientific community to provide medical care to the people affected by the accident. Responding to the appeal, the Government of the Republic of Cuba set up a comprehensive medical care programme for children of these areas which started in March 1990.

The programme began by selecting and classifying the children from affected areas that would travel to the island. This process was carried out by a Cuban medical team, in co-ordination with local health authorities and the support of the social organizations sponsoring this endeavour.

The principal criterion of selection was the health of the children considered and the possibility of receiving medical assistance in Cuba. The surface contamination of the localities where the children came from, the children's internal contamination and other radiological parameters were not known to the team in charge of selection, and were thus not taken into account. Children from areas where surface contamination from Chernobyl was highest were not received in Cuba.

The children selected were divided into four groups according to illness and required level of medical care. Group I included children with onco-haematological disorders, some 3% of all selected cases, who were cared for in specialized hospitals. Group II children had chronic or acute intercurrent diseases that required hospitalization upon their arrival in Cuba and represented some 17% of the selected cases. Group III children were affected by diseases that could be treated at outpatient services and represented approximately 60% of all cases. Group IV was made up of relatively healthy children, representing 20% of the total [1].

At their arrival in Cuba, the children in groups III and IV were lodged at a specially furnished children's sanatorium at Tarará beach, east of Havana. A medical care subsystem was set up there to determine the children's health condition, carry out preventive medical-stomatological therapeutical actions, physical and mental rehabilitation programmes and assess the impact of ionizing radiation on them through dosimetric and radiobiological studies [1].

The children of groups III and IV spent approximately 45 days at this institution. The children of groups I and II who received their post-hospital rehabilitation treatments at Tarará probably spent more time there.

Dosimetric and radiobiological studies were performed on children of groups III and IV. The main purpose of these studies was to establish the activity levels of ^{137}Cs and the corresponding doses of internal contamination by this radionuclide. Additionally, they were intended to aid in calculating doses under different conditions, to characterize the health as a whole of the children sampled and to evaluate the behaviour of the biological indicators with a high sensitivity to ionizing radiation.

2. COMPUTERIZED SYSTEM FOR THE RADIOLOGICAL EVALUATION OF PEOPLE LIVING IN AREAS AFFECTED BY THE CHERNOBYL NUCLEAR ACCIDENT

2.1. INTRODUCTION

A large amount of information is generated during the process of specialized care of people involved in or affected by a radiological or nuclear accident. This data must be organized, classified and analyzed as soon as possible. The EVACCID computerized system was developed for this purpose and allows automated processing and analyses of the results of medical, radiobiological and dosimetric studies.

2.2. STRUCTURE

EVACCID allows to control data, estimate physical magnitudes in dosimetry and radiological protection, and establish correlations of all parameters. This information can be broken down into geographical regions, age groups, dose intervals, values per laboratory analysis and types of disease or pathology identified.

EVACCID is divided into modules guaranteeing appropriate user interaction and organization of the data obtained. The system's general diagram is shown in Figure 1.

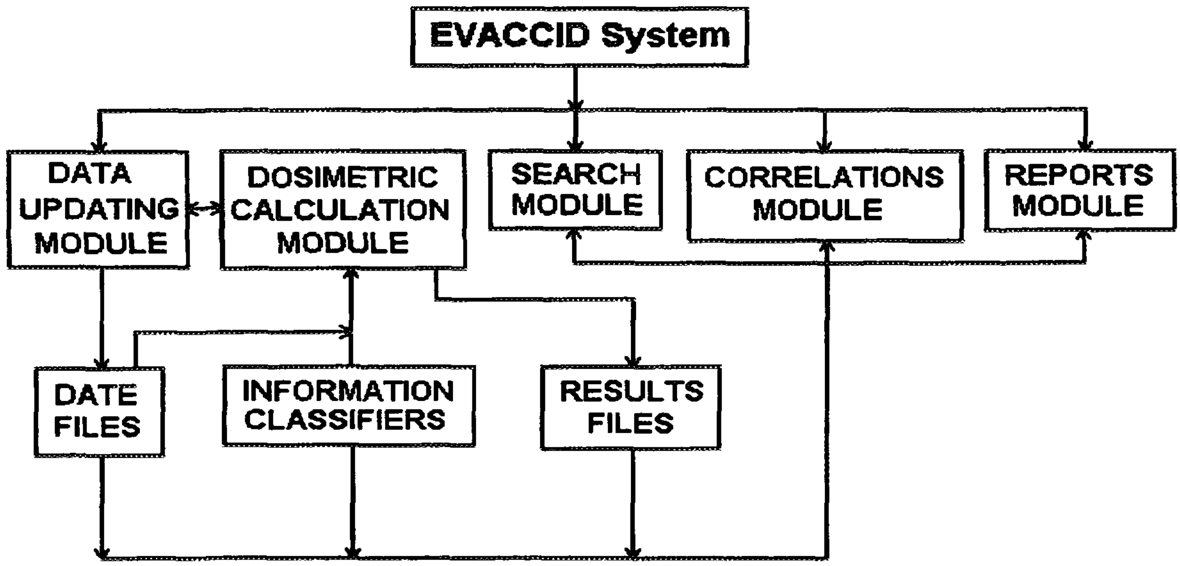


Fig. 1. General diagram of the EVACCID system.

Data updating

The Data Updating module has several features, the most relevant being:

- General data of the person, covering: name, sex, age, place of residence during the accident, place where evacuated, eating habits, clinical history and dosimetric history numbers.
- Specific data for each case: weight, size, clinical and laboratory tests, pathologies, etc.

- Measurements: allows to update data from measurements of the body's activity such as measurement date, measurement of the background in the relevant region of spectrum, identification of the measurement system used.

- Classifiers: allows to update the region of location, area surface contamination values, classification of pathologies and diseases, eating habits and other relevant data.

- All these data are coded and stored in data files to be used later in dosimetric estimates.

Dosimetric calculation

The Dosimetric Calculation module was designed to estimate the following values:

- Total and specific activity of the relevant radionuclide (^{137}Cs) as measured in the person.

- Estimation of external radiation dose based on ground surface contamination by ^{137}Cs and by other radionuclides.

- Thyroid dose estimation based on ^{137}Cs ground surface contamination and knowledge of the $^{131}I/^{137}Cs$ ratio.

- Estimation of dose by ^{90}Sr internal contamination based on ^{90}Sr ground surface contamination.

- Estimation of internal contamination dose based on ^{137}Cs whole-body measurement.

- Estimation of total dose, including the contribution of the aforementioned elements.

The methodologies used for calculating these estimates are presented in references [2, 3, ll, 13].

Search, correlations and reports

The Search, Correlations and Reports modules are obtained by data file inter-relation, data classifiers and dosimetric calculations. Correlations and reports may be made according to the following options:

- general data
- external doses
- whole body content
- internal doses
- total doses
- medical aspects.

Values of the whole body content or specific whole body content may be related to:

- regions of location

- distribution by range of activity
- distribution by age ranges
- activity/eating habits ratio
- ratio of activity of ^{137}Cs deposition in the environment.

Medical aspects include:

- behaviour of haematology indicators
- behaviour of thyroid indicators (TSH, T4 values and degree of hyperplasia)
- main clinical findings by specialty.

These may be correlated with surface contamination levels and dose values for the groups studied.

All data relating to any one person and contained in the system may be viewed on the screen or printed out at a terminal. Searches, reports and correlations may be made for groups of people based on common parameters, such as geographic location.

The system has a wide range of applications owing to its capacity to accumulate and store dosimetric and medical data, which can then be processed and correlated. It is particularly suited to radiological or nuclear accidents with repercussions beyond a nuclear facility's premises which fall within a value of between 4 and 7 on the Nuclear Event Scale.

3. CHARACTERISTICS OF THE DOSIMETRIC STUDY

The dosimetric study was based on environmental data available in Cuba from the regions affected by the accident and based on measurements of the children's ^{137}Cs body burden. A set of considerations and indirect deductions were made in order to reach an appropriate approximation level for radiological protection purposes. As a result, a conservative stand was taken, overestimating the dose. Despite the efforts made, it was not possible to obtain the surface contamination data of all the locations where the children came from.

The children were measured and the doses to which they had been exposed were assessed. Forecasts were then made on the levels of radionuclides in their body over the next 70 years, based on the predicted behaviour of radionuclides in the environment during the time frame considered.

The following steps were taken to prepare the study:

1. Assembly and calibration of two measurement systems to determine ^{137}Cs levels in the children's body.

2. Selection of children to be measured according to the levels of ^{137}Cs ground surface contamination in the locations where the children came from.

3. Radiological survey of each child selected.

4. Measurement of the body content and ^{137}Cs dose estimation.

5. Dose estimation through different pathways, including:

- External radiation with the contribution of several radionuclides.
- Internal contamination through ^{90}Sr.
- Hypothetical ^{131}I dose in thyroid.
- Total dose.

Dosimetric studies were performed on a total of 4506 children and adolescents between the ages of one and 17 from altogether 659 townships. Of the individuals studied, 69.3% came from the Ukraine, 22.5% from Russia and 8.1% from Belarus, as shown in Table I.

TABLE I. GENERAL CHARACTERISTICS OF THE GROUP OF CHILDREN STUDIED

Republic	Number of townships	Number of children	Age (years)	Sex (%)	
				M	F
Belarus	82	367	7 - 16	49.35	50.65
Ukraine	421	3121	1 - 17	53.99	45.99
Russia	156	1018	3 - 16	55.71	44.29
Total	659	4506	1 - 17	53.12	46.88

4. MEASUREMENTS OF BODY CONTENT AND ^{137}Cs INTERNAL DOSE ESTIMATION

4.1. INTRODUCTION

Of the gamma emitting radionuclides released during the Chernobyl accident, ^{137}Cs has the longest half-life. For this reason, it contributes significantly to the dose for a long period of time. It is possible to detect the presence of this radionuclide in the body of the persons living in the areas affected by the accident and thus derive an estimate of the internal dose.

4.2. METHODOLOGY

4.2.1. Measurements of body content

Two whole-body counters, with a partial shadow shield (5 cm, lead) and a stretcher geometry, were installed. A 150 × 100 mm NaI(Tl) detector and an MCA-01 locally-built multichannel analyser were used in each facility. Figures 2 and 3 show the geometry of measurement.

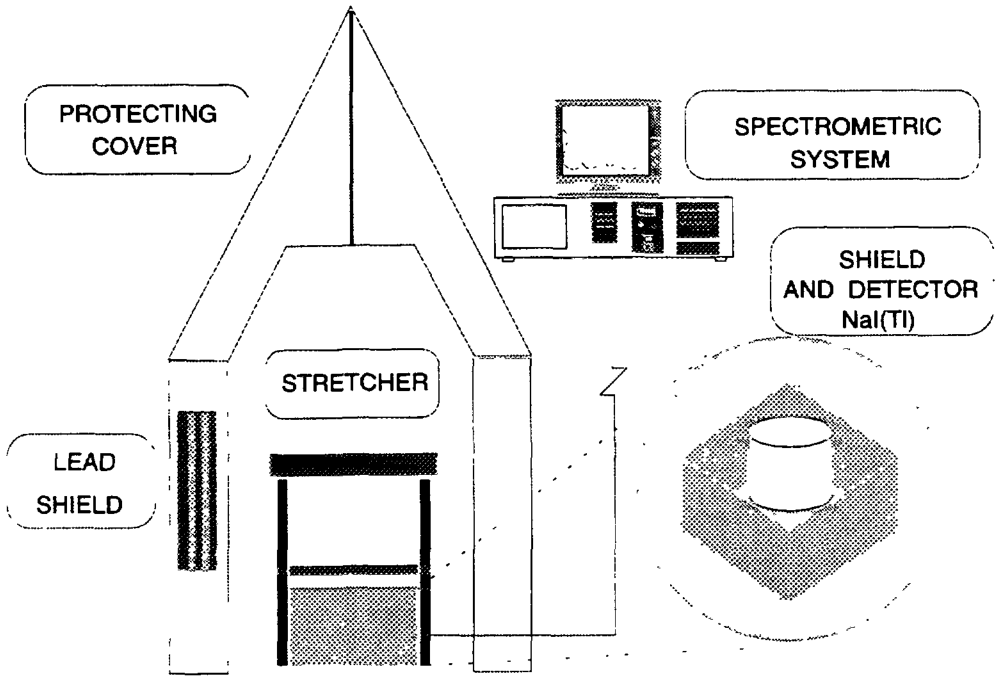


Fig. 2. Whole body counter – frontal view.

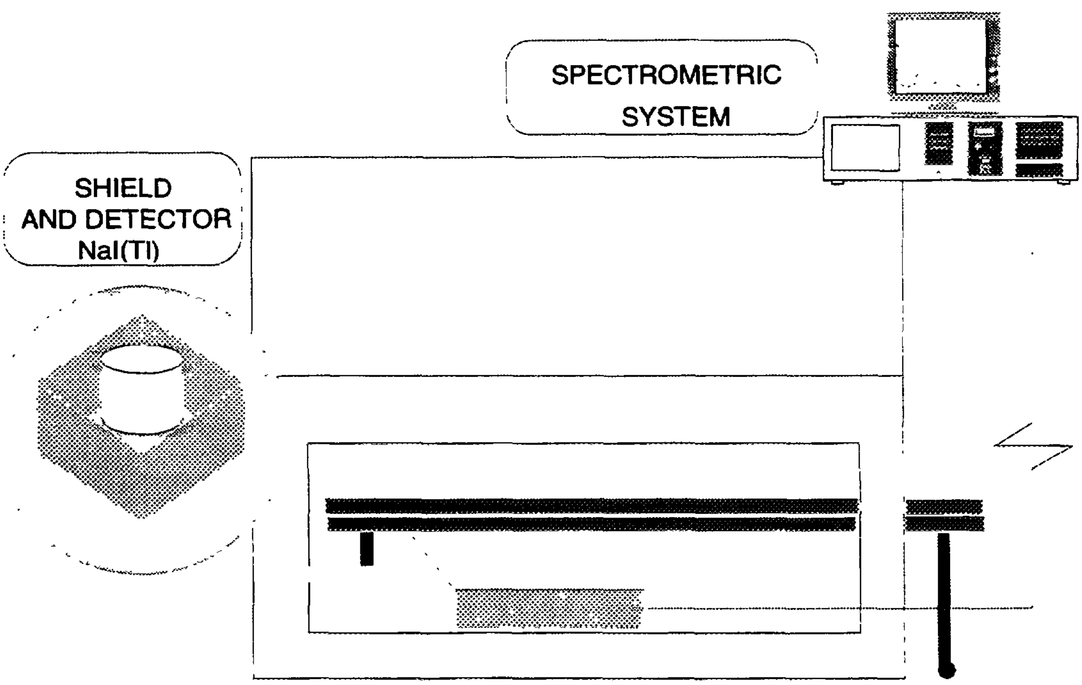


Fig. 3. Whole body counter – lateral view.

A set of phantoms made up of plastic containers was used to calibrate the system. The smallest was made to correspond to a child weighing 5 kg, the largest, to the 70 kg Reference Man [4]. The main characteristics of the phantoms are presented in Figure 4. The radionuclides used in the calibration were gamma emitters with 511-1460 keV energies: ^{85}Sr, ^{54}Mn, ^{137}Cs and ^{40}K. The phantom characteristics in terms of the activity of radionuclides measured are shown in Table II. The phantom used to measure background levels contained an amount of potassium and calcium proportional to the four weights considered [4, 7]. This allowed a more exact determination of ^{137}Cs, since the contribution of the ^{40}K present in each child was well known.

TABLE II. CHARACTERISTICS OF RADIONUCLIDES USED FOR CALIBRATION

Radionuclide	E (keV)	$T_{½}$	Reference Activity* (Bq)
^{54}Mn	836	310 d	366.76
^{85}Sr	514	65 d	1994.40
^{137}Cs	661	30 a	1285.51
^{40}K	1460	10^9 a	1064.00

*Reference activity on 19.4.1990.

Natural potassium (K) is composed of 93.25% of ^{39}K; 6.73% of ^{41}K and 0.0117% of ^{40}K. The human body contains 140 g of potassium, 120 g of which are in the soft tissue [4].

The content of this radionuclide, depending on age, varies as follows [5]:

$$^{40}K \text{ (37 KBq/kg)} = 1.5\text{-}0.00985 \times \text{Age} \tag{1}$$

As to calcium, the human body contains 1000 g of this substance, 800 g of which are found in the bones and 13 g in the teeth; the remainder lies in the soft tissue and the rest of the body.

The presence of these isotopes in the phantoms allows to quantify the contribution of ^{40}K to the region of interest of ^{137}Cs in the spectrum. The calcium simulates the radiation dispersion in bones. The background simulator contains 996 g of calcium and 136.21 g of natural potassium. This represents 0.0159 g of ^{40}K with an activity of 4276.9 Bq and a specific activity of 62.89 Bq/L.

In the case of the ^{137}Cs, the detection efficiency for each phantom was adjusted through the minimal square method, depending on its weight/height ratio [6].

$$\varepsilon_i = A(1)\,(P/T)_i^{\,1/2} + A(2) \tag{2}$$

where

ε_i ....is the detection efficiency for the phantom i at the photopeak,

$(P/T)_i$ ....is the weight/height relationship of the phantom i where the weight is expressed in kg and the height in cm,

and A(1) and A(2) ...are the gradient and intersection of the adjusted line.

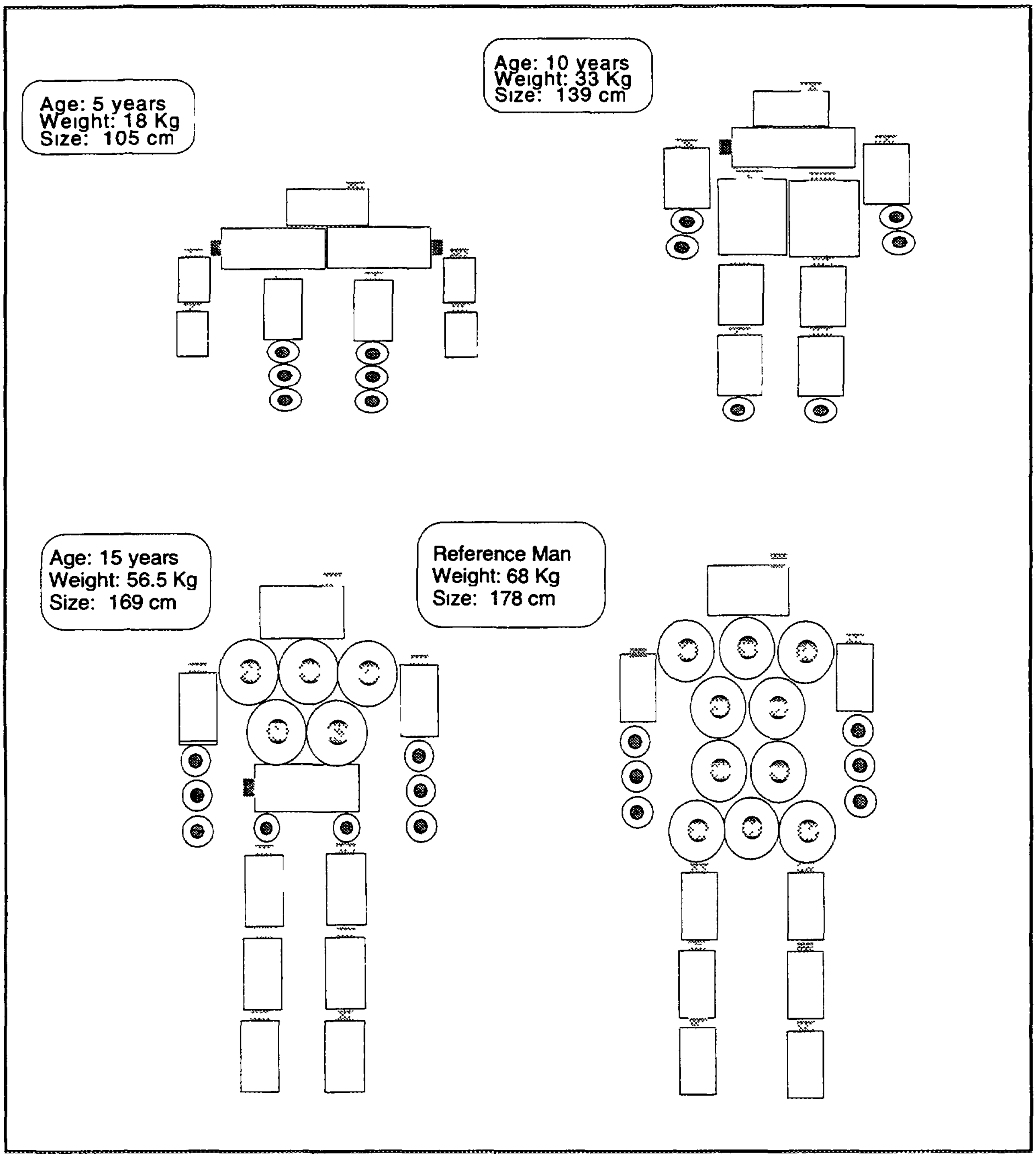


Fig. 4. Characteristics of phantoms used for calibration.

The minimum detectable amount (MDA) was established according to the following relation [5]:

$$MDA_i = (4.65\ \sigma_b + 3) / \varepsilon_i \bullet Y \bullet T \qquad (3)$$

where

σ_b............................ is the deviation of the background measurement in the spectrum region of interest,

Y.............................. is the yield of type i radiation per nuclear transformation,

T.............................. is the measurement time (equal to 25 minutes), and

ε_i .... is the detection efficiency for the phantom i at the photopeak.

The behaviour of MDA with regard to weight and height is shown in Fig. 5. Detection efficiency and minimum detectable amount values are shown in Table III. The measurement error of an activity was estimated at 32% with a 90% confidence interval.

TABLE III. WHOLE BODY COUNTER CHARACTERISTICS

Radionuclide	Counter 1		Counter 2	
	ε (cps/Bq)*	MDA (Bq)**	ε (cps/Bq)	MDA (Bq)
^{137}Cs	3.09 E-3	105	2.66 E-3	126
^{40}K	1.63 E-3	1036	1.69 E-3	804

* Phantom of Reference Man.
** Measurement time: 25 min.

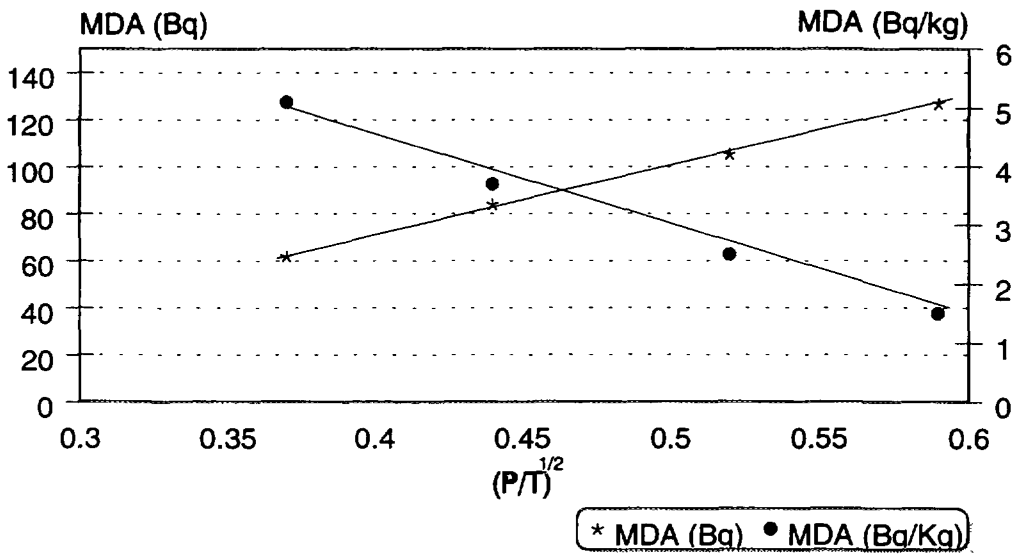


Fig. 5. Relation of the minimum detectable activity with weight and height.

The behaviour of activity distributions measured in the children of each region was studied. The distribution was found to be log-normal; it was verified by the Kolgomorov-Smirnov test [7]. The selection of the children to be measured was done taking into account the ^{137}Cs surface contamination values in the regions where they are now living.

Table IV compares selected features of the whole body counters used in the present study with those used in the International Chernobyl Project.

TABLE IV. WHOLE BODY COUNTERS: CUBA AND INTERNATIONAL CHERNOBYL PROJECT

	Cuba	ICHP
Geometry	Stretcher	Chair
Detector	NaI(Tl) 15 × 10 cm	NaI(Tl) 7.6 × 7.6 cm
Calibration	Phantoms 5 - 70 kg	Reference Man
Measured time	25 min	5 min
MDA (kBq)	Variable 0.105 Children 0.126 Adults	Variable 0.19 Children 0.74 Adults
Number of measurements	4506	9000
Characteristics of the distribution	Log-normal	Log-normal
Interval of measured activity	1.5 - 565 (Bq/kg)	2.16 - 4070 (Bq/kg)

4.2.2. Estimation of internal dose

The methodology used to calculate the internal contamination dose followed the recommendations of Publication 30 of the International Commission on Radiological Protection (ICRP) [8]. According to the ICRP, the dose-equivalent ($H_{50,T}$) for any body organ or tissue after a unitary incorporation is calculated as follows:

$$H_{50,T} = 1.6 \times 10^{-10} U_s \, \text{SEE} \, (T <\!- S) \; (S_v/Bq) \tag{4}$$

where

U_s .... is the number of nuclear transformations in the organ during the 50 years following the incorporation per Bq incorporated in a source region S

SEE (T<-S).............. is the specific effective energy deposited in T per transformation in S expressed in (Sv/Bq/s), and

1.6×10^{-10} .... is the conversion factor to the unit Sv (J.g/MeV.kg).

The quantity of U_s transformations is determined as:

$$U_S = \int_0^T q(t) \bullet d(t) \tag{5}$$

where

q(t)............................ is the activity present in the organ in time t.

For the case of assumed chronic incorporation due to an intake rate of 1 Bq/d from the moment of the accident, it is determined that:

$$q(t) = A / T \int_{0}^{T} r_S \bullet d(t) \tag{6}$$

where

A / T .... is the activity incorporation rate (Bq/d),

r_s .... is the retention function for ^{137}Cs in the body and is expressed as follows:

$$r_S = a \bullet e^{-\ln 2t/b} + c \bullet e^{-\ln 2t/d} \tag{7}$$

where

t .... is the time elapsed between the day on which the children left their country and the day of measurement.

The parameters a, b, c and d vary according to age. They were obtained from ICRP 67 [9] and are presented in Table V.

TABLE V. BIOKINETIC DATA FOR ^{137}Cs

Age	a(days)	b(days)	c(days)	d(days)
0-12 months	--	--	1	16
1-2 years	--	--	1	13
> 2-7 years	0.45	9.1	0.55	30
> 7-12 years	0.3	5.8	0.7	50
> 12-15 years	0.13	2.2	0.87	93
Adults	0.1	2.0	0.9	110

The preceding assumes 1 Bq of incorporated activity. To obtain a dose equivalent, the dose conversion factor τ_{50} (Sv/Bq) is expressed as:

$$H_{50,T} = \tau_{50} \bullet A_{inc} \tag{8}$$

where

A_{inc} .... is the incorporated activity (intake).

Taking into account the time elapsed between the day on which the children left their country and the day of measurement, it is necessary to correct the activity measured:

$$A = \frac{A_{med}}{Frs} \qquad (9)$$

where

A .... is the activity in the body of the children when they arrived in Cuba,

A_{med} .... is the activity of ^{137}Cs measured in the body of the children (Bq), and

Frs .... is the retention factor obtained by evaluating the retention function $r_S(t)$ for the time elapsed between the arrival of the children in Cuba and the day of measurement.

The incorporated activity (A_{inc}) is determined by the activity present in the children's organism at the time of arrival. It is expressed by the relation:

$$A_{inc} = \frac{A}{F_{rc}} \qquad (10)$$

where

F_{rc} .... is the retention factor obtained by evaluating the retention function $r_S(t)$ for the time when the incorporation occurs, assuming incorporation as chronic.

The specific effective energy for radiation of type i is defined as:

$$SEE(T \leftarrow S) = \frac{\sum_i Y_i \bullet E_i \bullet AF(T \leftarrow S)_i \bullet Q_i}{M_T} \text{ (MeV/g•des)} \qquad (11)$$

where

$\sum_i$ .... is understood to represent all the radiations produced per disintegration,

Y_i .... is the yield of type i radiation per nuclear transformation,

E_i .... is the average or unique energy of type i radiation,

$AF(T \leftarrow S)_i$ .... is the absorbed fraction in T per transformation in S for radiation i,

M_T .... is the mass of target organ T (from ICRP 23), and

Q_i .... is the radiation weighting factor corresponding to radiation i (from ICRP 60).

For the calculation of SEE(T<----S) both the beta and gamma disintegration of ^{137}Cs (^{137m}Ba and ^{137}Ba) and the age factor were taken into account.

The absorbed energy values reported for different ages were obtained from Ref. [10] where the source and target organs were the whole body.

The values of $AF(T \leftarrow S)_i$ at other ages are obtained by linear interpolation based upon the reciprocal quotient of the total body mass.

Taking into account that AF changes with the age, the values of $SEE(T \leftarrow S)$ were calculated based on the average time period each child was exposed to radiation from the accident.

4.3. RESULTS AND DISCUSSION

4.3.1. Measurements of body content

As mentioned earlier, the highest number of measurements were taken on Ukrainian children, which represented some 70% of all the children cared for. Table VI shows the general results of the measurements, broken down according to the children's republic of origin.

TABLE VI. GENERAL RESULTS OF ^{137}Cs BODY MEASUREMENTS OF CHILDREN FROM THE THREE REPUBLICS STUDIED

Republic	Number of children measured	Measurement with total activity higher than MDA		Total activity interval	Specific activity interval
		Amount	%	(kBq)	(Bq/kg)
Belarus	367	324	88.3	0.1- 8.5	1.5-363
Ukraine	3121	2239	71.7	0.1-31.8	1.5-565
Russia	1018	548	54.1	0.1-11.5	1.5-195
Totals	4506	3111	69.1	0.1-31.8	1.5-565

Sixty-nine per cent of the children were found to show ^{137}Cs activity in the body with values exceeding the minimum detectable amount. Values fluctuated between 1.5 and 565 Bq/kg. Of the children measured, 90% showed a specific activity under 20 Bq/kg. Figure 6 shows the results in the main regions studied, where the mean value was (4.3 ± 2.1) Bq/kg for 634 children measured (standardized variable $z=(x-\mu) / \sigma$). The activity distribution had a log-normal character in each region studied.

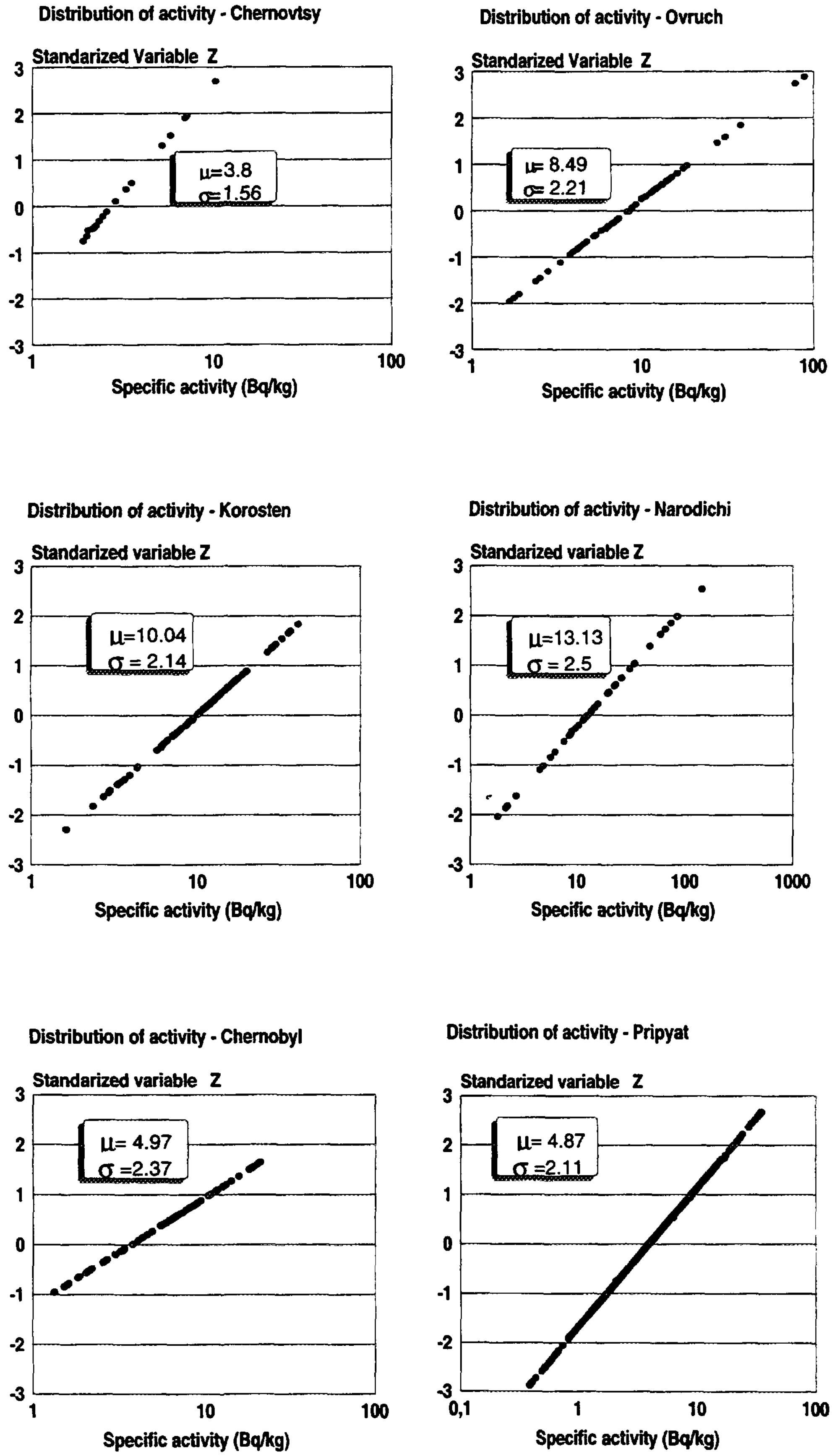
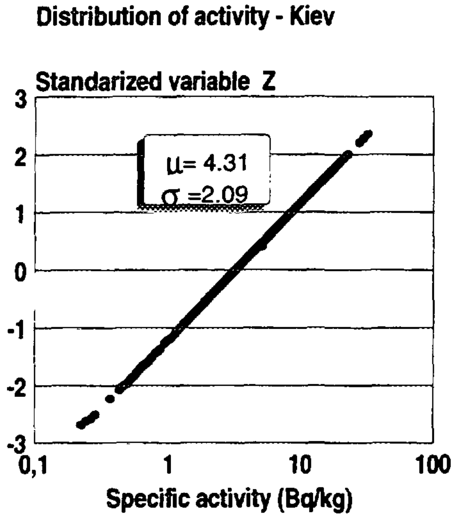


Fig. 6. Distribution of specific activity in the main locations studied.



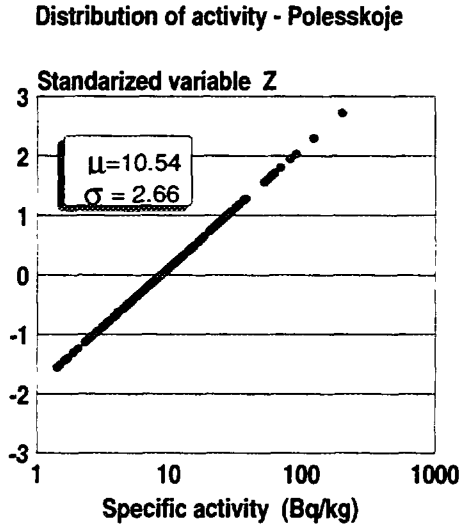


Fig. 6. Cont.

Table VII presents the values of μ and σ for the locations of greatest interest, based on the number of children surveyed.

TABLE VII. SPECIFIC ACTIVITY PARAMETERS IN THE REGIONS STUDIED

Regions	Surface contamination (kBq/m^2)	Number of children measured	Mean specific activity (Bq/Kg)	
			μ	σ
Chernigov	7.4	134	5.4	2.2
Kiev	22.2	634	4.3	2.1
Chernovtsy	59.2	37	3.9	1.6
Ovruch	74.0	58	8.5	2.2
Korosten	296.0	78	10.0	2.1
Narodichi	632.7	50	13.1	2.5
Polesskoje	910.0	155	10.5	2.7
Pripyat	Evacuated	607	4.9	2.1
Chernobyl	Evacuated	89	5.0	2.4

Figure 7 shows the values of activity measured for the different age groups in the region of Kiev. It is to be noted that a larger number of measurements were made on children 8 to 14 years old. The value interval is similar for each age, which may confirm that measured activity values have no direct relationship with the age of the children. Similarly, no link was found to exist between internal contamination levels and eating habits. The pattern of activity values is similar for children from the regions presented in Table VII.

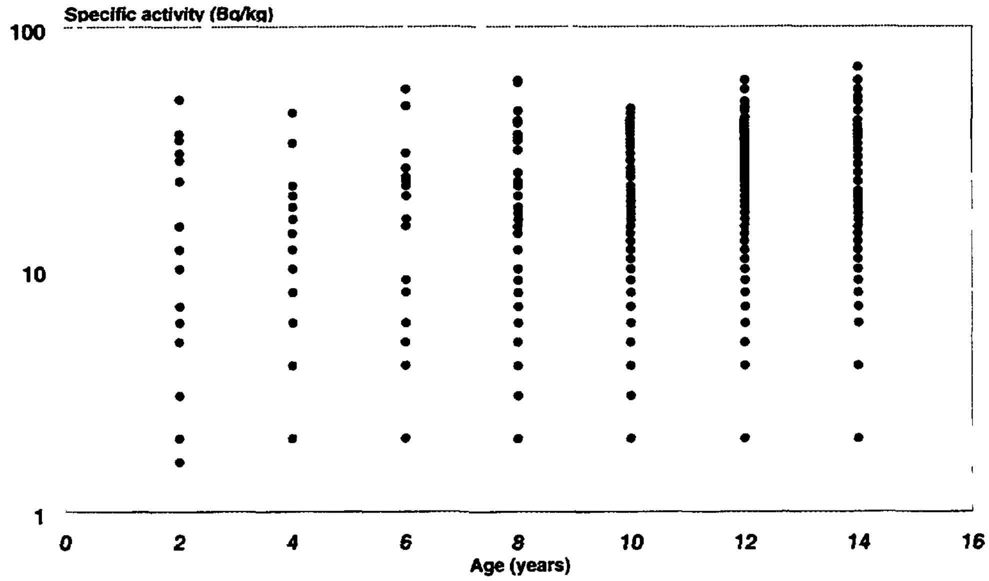


Fig. 7. Mean activity values for the different age groups in the area of Kiev.

The relationship between mean values of specific activity measured on the children surveyed and surface contamination levels is shown in Figure 8. Higher levels of contamination in the body were noted as surface contamination rose, although it is not possible to establish a defined function with appropriate statistical rigour. This might be due to a relaxation of the restrictions on the intake of contaminated food produced in the children's region of origin. This direct relationship contradicts the results obtained by the International Chernobyl Project [11], which determined that as surface contamination increased, there was a decrease in values of measured body activity in the areas surveyed, attributed to the effectiveness of restrictive measures against the intake of contaminated food.

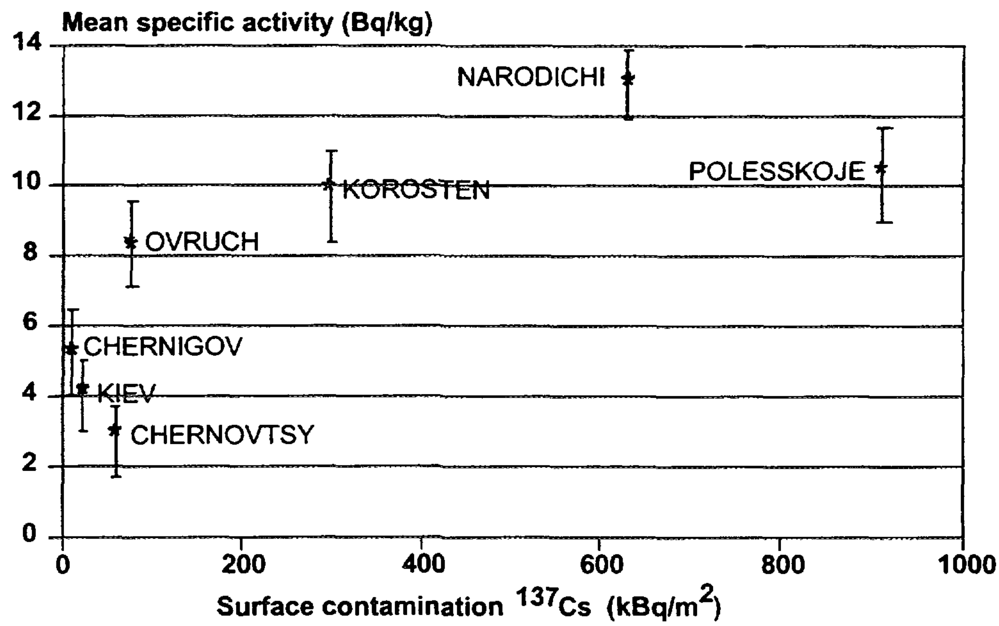


Fig. 8. Relation between mean values of specific activity and levels of surface contamination.

4.3.2. Estimation of internal dose

The integrated effective ^{137}Cs dose was calculated, assuming a model of chronic intake, for one year of study and 70 years beginning on the first intake. Figure 9 shows the distribution of children per dose interval. As can be seen, 55 per cent of the children received doses smaller than 100 μSv. The maximum values estimated are in mSv units. The dose range calculated was <1-9 mSv.

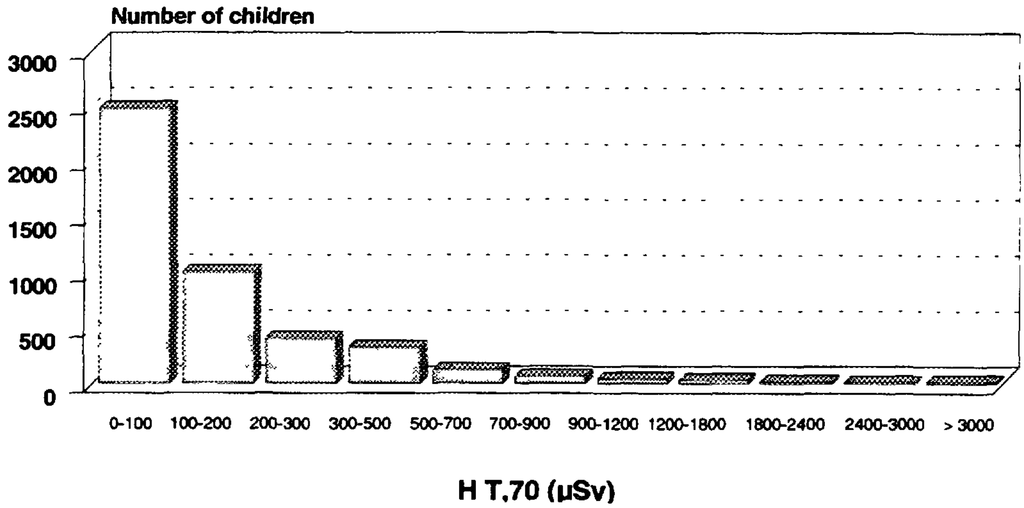


Fig. 9. Distribution of children per interval of ^{137}Cs integrated dose.

4.4. CONCLUSIONS

The dosimetric study provided Cuban specialists the opportunity to design, construct and install two whole body counters and to establish methodologies of calibration adapted to children. Moreover:

- The levels of internal contamination in the universe studied fluctuate between 1.5 and 565 Bq/kg, with 90% of the individuals surveyed showing activities under 20 Bq/kg.
- The distribution of activity measured has a log-normal character in each geographical area studied.
- The relationship between the ^{137}Cs levels measured and the children's age and eating habits does not have a defined functional character.
- An increase in the mean values of specific activity was observed with higher levels of contamination on the ground.
- In the dose projection over a 70 year period, 55% of the children received a dose smaller than 100 μSv, with maximum values reaching mSv units.

5. DOSE ESTIMATION THROUGH DIFFERENT PATHWAYS

5.1. INTRODUCTION

In nuclear accidents, the main irradiation pathways that contribute to the doses after the radioactive cloud passes over the affected zone are the external irradiation caused by radioactive materials in the environment and radionuclide intake through the food chain. The irregular deposition of scattered materials makes it necessary to draw up regional estimations for dose calculations [11, 12].

Despite the limited information available in Cuba about the surface contamination on the ground and the doses received by the children surveyed, it was decided to assess approximately the doses incurred through the different paths of irradiation.

Dose estimates include:

- External irradiation due to the deposition of contaminants in the environment.
- Internal contamination due to the presence of ^{90}Sr and ^{131}I in the body of the children.
- A total value which includes all the foregoing components as well as the internal dose estimate for ^{137}Cs (Section 4).

The calculations covered the year during which the children were surveyed and served as a basis for a 70-year projection [13].

5.2. METHODOLOGY

5.2.1. External radiation dose estimation

The preliminary data used to calculate external radiation estimates were taken from a survey drawn up in Cuba which provided information on each child's city or township of origin, location following the accident, lifestyle and eating habits at the time of the accident and thereafter. Estimates were drawn from official data issued by the Ukraine and international agencies which indicated the dose rates and surface contamination values of the children's respective areas of origin [2, 11, 12, 14, 15].

The calculation procedure used is based on the UNSCEAR model [2], a shortened description of which follows.

During the first month after deposition, a number of short-lived emitters, including ^{132}Te, ^{132}I, ^{131}I, ^{140}Ba, ^{140}La and ^{136}Cs, were important components of the total external gamma exposure rate. For several months thereafter, ^{103}Ru and ^{106}Ru were also noticeable, but since then only ^{134}Cs and ^{137}Cs have been of any significance. External gamma exposure rates will remain elevated for some years due to the presence of ^{134}Cs, and for decades, due to ^{137}Cs contamination.

The calculation of the external gamma dose beyond one month is based on the measured total deposition of ^{134}Cs and ^{137}Cs and, although less important, that of ^{103}Ru, ^{106}Ru, and ^{131}I. The conversion factors for long term deposition to dose rate depend on the penetration of these radionuclides in the soil. Change with time is accounted for by using factors appropriate for a relaxation depth of 1 cm during the first year, and 3 cm thereafter.

For the radionuclide i, the equation for the calculation of the external gamma effective dose for the time period between one month and one year is:

$$E_{e2}(i) = \frac{F(i)}{\tau(i)} \bullet \phi_{e2}(i) \bullet [e^{-\tau(i)1a/12} - e^{-\tau(i)1a}] \bullet [1 - F_o \bullet (1-F_s)] \bullet [1-F_p \bullet (1-F_u)] \quad (12)$$

where:

$E_{e2}(i)$........................ is the external gamma effective dose from one month to one year (Sv),

$F(i)$........................... is the deposition density (Bq/m^2),

$\phi_{e2}(i)$ .... is the deposition density to effective dose conversion factor during the period between one month and one year (relaxation depth of 1 cm) (Sv per Bq/m^2),

τ................................ is the radioactive decay constant (a^{-1}),

F_p............................. is the urban fraction of a country's population (Fp = 0.5),

F_u............................. is the fraction of the deposition that remains fixed on urban surfaces (Fu = 0.5),

F_o .... is the indoor occupancy factor (Fo = 0.8),

and F_s .... is the building shielding factor (Fs = 0.2).

Under the assumed parameters, the overall reduction for occupancy and shielding of buildings is 0.36 and the reduction for urban areas is 0.75.

Table VIII shows the outdoor effective dose per unit deposition density ($\phi_{e2}(i)$) for five important radionuclides. It is possible to obtain the contribution of these radionuclides to the effective dose per ^{137}Cs unit deposition density using the median value of the ratio of each of these radionuclides to ^{137}Cs in deposition. The transfer factor is obtained by multiplying the conversion factor $\phi_{e2}(i)$ by this ratio, and combining it with the factors F_o, F_s, F_u, and F_p set forth in expression (12).

The dose projected, beyond one year after deposition, is quantified as follows:

$$E_{e3}(i) = \frac{F(i)}{\tau(i)} \bullet [\phi_{e3}(i) \bullet e^{-\tau(i)1a}] \bullet [1-F_o \bullet (1-F_s)] \bullet [1-F_p \bullet (1-F_u)] \quad (13)$$

TABLE VIII. TRANSFER FACTORS FROM DEPOSITION TO EFFECTIVE DOSE DUE TO EXTERNAL IRRADIATION WITHIN THE FIRST YEAR

Radionuclide	Outdoor effective dose $\frac{\mu Sv \cdot m^2}{kBq}$	Ratio to ^{137}Cs	Transfer factor components $\frac{\mu Sv \cdot m^2}{kBq}$
First month All	15	------	5
Second to twelfth month:			
^{137}Cs	8.04	1	2.2
^{134}Cs	18.6	0.5	2.5
^{103}Ru	0.691	1.6	0.3
^{106}Ru	2.09	0.5	0.28
^{131}I	0.015	6.2	0.025
Total (first year)	-----	-----	10

The deposition density to effective dose factor, $\o_{e3(i)}$, to be used beyond one year after deposition, uses a relaxation depth of 3 cm. The transfer factors for this time frame are provided in Table IX.

TABLE IX. TRANSFER FACTORS FROM DEPOSITION TO EFFECTIVE DOSE DUE TO EXTERNAL IRRADIATION AFTER ONE YEAR

Radionuclide	Outdoor effective dose $\frac{\mu Sv \cdot m^2}{kBq}$	Transfer factor components $\frac{\mu Sv \cdot m^2}{kBq}$
^{137}Cs	264.0	71.3
^{134}Cs	36.2	4.9
^{106}Ru	1.65	0.2
Total for the period beyond one year		76

5.2.2. Estimation of ^{90}Sr internal dose

The estimation of the effective dose caused by exposure to ^{90}Sr was limited to a small group of 1344 children from the areas where the values of environmental contamination by ^{90}Sr are known.

All internal dose calculations were based on the children's length of stay in Cuba and a 70-year projection which assumes they will continue to live in the same region after returning home.

There is no data available which allow to reliably estimate the internal dose attributable to ^{90}Sr and reflect the local conditions in the contaminated areas. Only an approximation is possible by applying the transfer factors derived by UNSCEAR from global fallout [14]. The average values of these transfer factors are:

- Deposition to diet .... 4 Bq • year/kg per kBq/m^2

- Transfer of diet to the bones .... 38 Bq • year/kg per Bq • year/kg

- Transfer to the dose:
  +Bone marrow .... 1.9 µGy per Bq • year/kg
  +Bone lining cells .... 4.2 µGy per Bq • year/kg

The consecutive multiplication of these factors expresses the transfer factors from deposition to the absorbed dose. By applying the tissue weighting factors of 0.12 for bone marrow and 0.03 for bone lining cells, one obtains the transfer factor from deposition to the effective dose:

- Deposition to absorbed dose:
  +Bone marrow .... 290 µGy per kBq/m^2
  +Bone lining cells .... 640 µGy per kBq/m^2

- Deposition to effective dose .... 54 µSv per kBq/m^2

The application of these transfer factors to the reported deposition values of ^{90}Sr provides an estimate of the internal dose.

5.2.3. Estimate of ^{131}I dose in thyroid

Because of the physical and metabolic characteristics of ^{131}I, it was not possible to evaluate the dose in the thyroid gland direct or environmental measurements in the sample group of children assisted in Cuba. However, as even an approximate estimation would prove useful to Cuban medical specialists, the known relationship between ^{131}I and ^{137}Cs in deposition and in the air was chosen as the single possible way to calculate the ^{131}I dose in the thyroid. The mean value of this quotient in deposition, for all European countries, was 6.2. Higher values were reported for Belarus (15), Russia (16) and Ukraine (33). These values were applied to the deposition of ^{137}Cs to estimate the deposition of ^{131}I, as shown in Table X.

TABLE X. CONCENTRATION OF ^{131}I IN THE ENVIRONMENT BASED ON THE CONCENTRATION OF ^{137}Cs

Republics	^{131}I/^{137}Cs quotient	^{137}Cs concentration in the environment (kBq/m^2)	^{131}I concentration in the environment (kBq/m^2)
Belarus	15	a*	15 * a
Russia	16	b	16 * b
Ukraine	33	c	33 * c

* In specific territories.

Thyroid dose estimates were calculated for infants under one year of age, children aged 5, and adults. The breathing rates were assumed to be 3.8 m^3/d, 8 m^3/d and 22 m^3/d and the consumption of milk 200 L/y, 260 L/y and 260 L/y, respectively. The leafy vegetable consumption was put at 5 kg/y, 10 kg/y and 37 kg/y, respectively. The concentration of ^{131}I in air indoors was assumed to be less than outdoors by a factor of 0.3. The occupational factor of 0.8 was chosen. The dose factors in thyroids per unit of intake of ^{131}I via inhalation were put at 2.2 μGy/Bq, 1.3 μGy/Bq and 0.27 μGy/Bq for infants, children and adults, respectively, and 3.6 μGy/Bq, 2.1 μGy/Bq and 0.44 μGy/Bq via ingestion. The foregoing values allow to determine the transfer factors of the deposition of ^{137}Cs in order to estimate the ^{131}I dose in the thyroid (Table XI).

TABLE XI. TRANSFER FACTORS FOR DOSE ESTIMATION IN THYROID (^{131}I), BASED ON DEPOSITION OF ^{137}Cs

	Transfer factor (μGy per kBq/m^2)			
	Inhalation		Ingestion	
Republics	N	A	N	A
Belarus	62	36	950	270
Russia	60	34	1000	290
Ukraine	52	30	2100	590

N=child, A=adult, based on UNSCEAR [2].

For these estimates, it was assumed that the children had not been subject to iodine prophylaxis, and that they had consumed without restriction foodstuffs sold commercially.

5.2.4. Total dose estimation

The total dose was estimated as the sum of each of the following components of the dose:

- Effective dose for external radiation.
- Effective dose caused by ^{137}Cs, ^{90}Sr and ^{131}I.

5.3. RESULTS AND DISCUSSION

5.3.1. External radiation dose

The distribution of children per external radiation dose intervals for the year during which the survey was carried out in Cuba (Figure 10) shows that 90% of the children received radiation doses under 2 mSv, while only 5% received doses higher than 5 mSv. The highest estimate for that period was 30 mSv. The behaviour of the dose values for the year of study and the 70-year projection is linear.

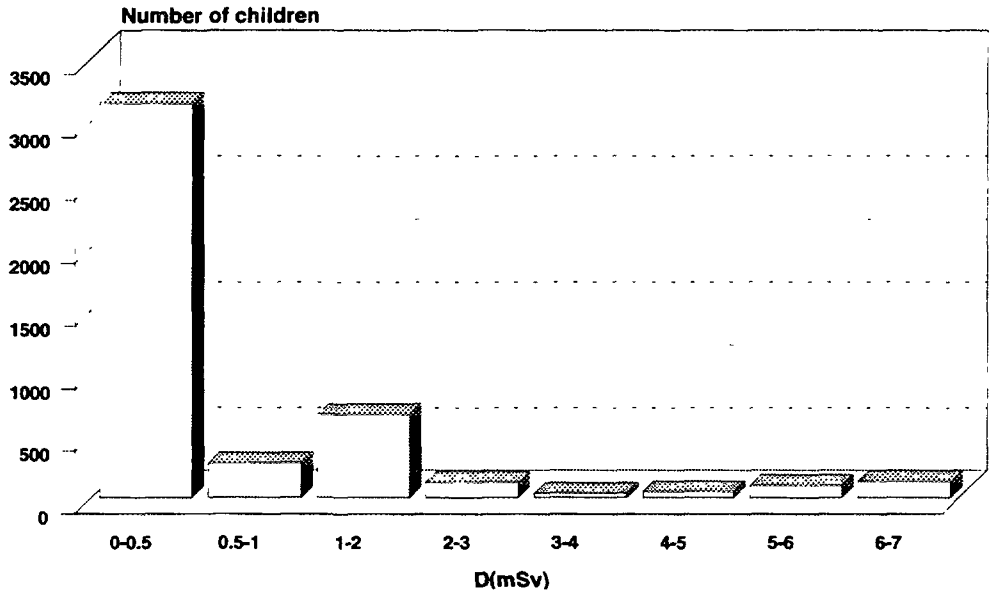


Fig. 10. Distribution of children per external dose (year of study).

5.3.2. Internal dose

The distribution of the effective doses due to ^{90}Sr shows that 25% of the children received doses higher than one mSv unit. However, maximum doses do not exceed 5 mSv.

The hypothetical estimation of thyroid-absorbed doses in some regions showed values of up to 2 Gy. It should be noted that this is a conservative estimate since an ^{131}I / ^{137}Cs quotient in the environment is assumed owing to the lack of specific data by location. It is estimated that 44% of the children received doses higher than 40 mGy in the thyroid.

5.3.3. Total doses

The contribution of all dose components is outlined in Table XII, which shows parameter dose intervals for the year of study following the accident and for a projected period of 70 years. The highest contributors in the first time interval are external radiation and the hypothetical contribution of ^{131}I. On the whole, external radiation is the main contributor. The distribution of children per total dose interval is shown in Figure 11, which indicates that 90% of the children sampled received total doses below 5 mSv. The maximum values do not exceed 0.2 Sv.

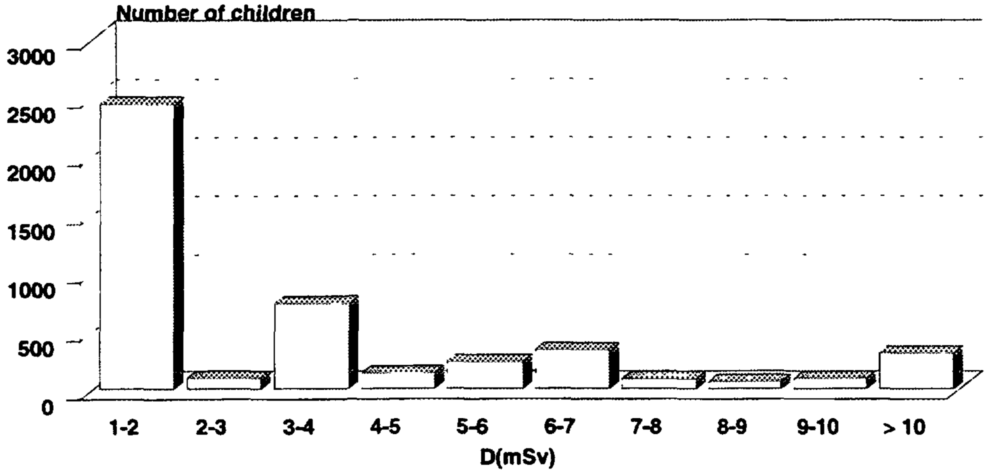


Fig. 11. Distribution of children per total dose (year of study).

When comparing these results with other studies [2, 11], the following differences were noted:

- In the external radiation dose estimation, a 0.75 correction value for urban areas is included. For this reason, this dose component is lower than that provided in the reference literature.
- Estimates of ^{90}Sr and ^{137}Cs internal doses fall within the same intervals (Figure 12).
- The absorbed doses of iodine in the thyroid fall within the same intervals. Due to the level of uncertainty of dose values, some authors do not consider this element to be a component of the total dose. In this paper, the hypothetical thyroid dose estimate is contained in Table XII, considerably increasing the total dose values (not included in Figure 12).

TABLE XII. GENERAL RESULTS OF THE GROUP OF CHILDREN STUDIED

Dose component	Dose intervals (mSv)		
		Year of study	70 year projection
External doses		<1 - 30	<1 - 120
Internal doses	^{137}Cs *	<<1 - 8.5	<<1 - 9
	^{90}Sr	<1 - 3	<1 - 5
	^{131}I **	<1 - 60	<1 - 60
Total doses		<1 - 85	<1 - 170

* Assuming chronic intake up to the year of study.

** Effective dose.

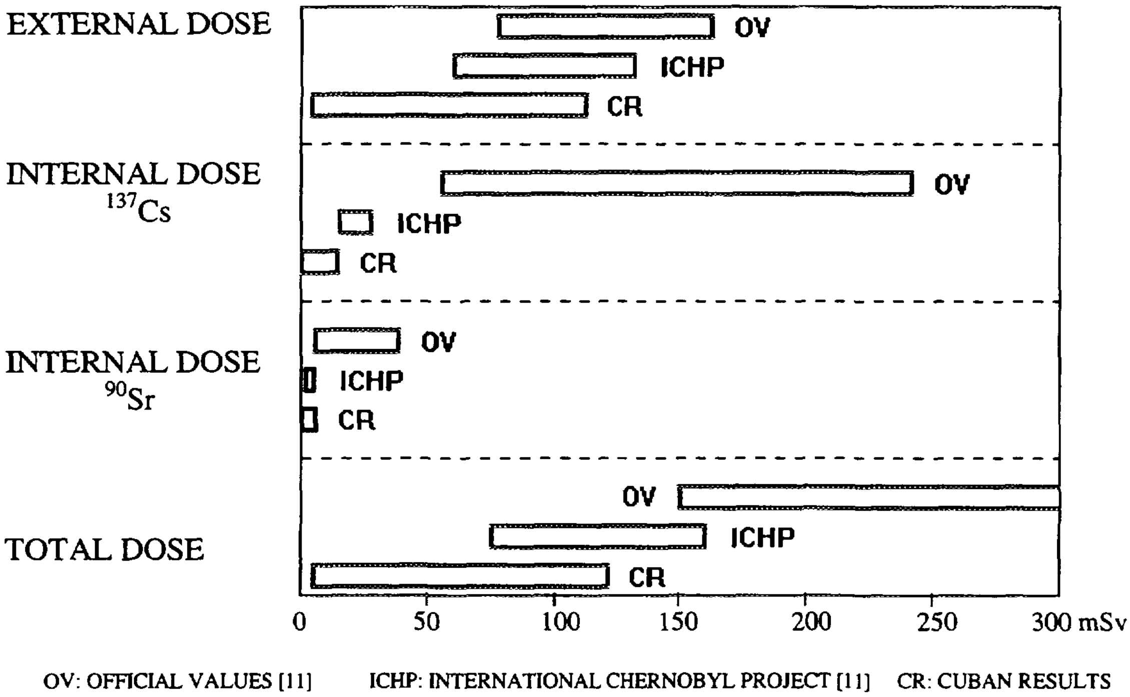


Fig. 12. Dose intervals compared by study.

The dosimetric models used to estimate doses were applied to the conditions specific to the Chernobyl accident. However, it must be noted that:

- The values of surface contamination are known for certain geographical areas where contamination is not homogeneous. The models assume contamination to be homogeneous.

- As the characteristics of soils change (in terms of density, salinity, etc.) so does their capacity to retain radionuclides. The dosimetric models apply to a specific kind of soil.

- The food contamination values in the children's areas of origin are not known with certainty. In addition, food contamination is calculated based on the mean values of food consumption, which are not always reliable.

- The $^{131}I/^{137}Cs$ surface contamination values are known for specific geographical regions and made extensive to entire republics.

- In the case of ^{90}Sr, the model is based on a fallout behaviour which does not take into account the chemical composition and characteristics of soils where fallout from the Chernobyl accident was deposited.

- The internal dose of ^{137}Cs is calculated on the basis of a model of chronic intake, which can not be verified in practice, as neither the food habits nor the food contamination levels are known.

- Shielding factors, as well as occupational factors, are used to estimate building contamination doses; they cannot be verified in practice.

The foregoing considerations increase the uncertainty of external radiation and internal contamination dose estimates. However, bearing in mind the availability of the contamination data for all the elements of the ecosystem affected by the accident, the possible errors in the generalizations of the models as well as the practice of overestimating the doses, the values determined in the present study for each irradiation pathway lie within low radiation dose levels and are in agreement with the results obtained by the International Chernobyl Project.

5.4. CONCLUSIONS

Estimating doses by looking into the different radiation pathways allowed a more precise knowledge of the models used internationally. The considerations applied to Chernobyl made it possible to confirm that:

- As a dose component, external radiation was the most important contributor to the total dose, with values of between <1 and 120 mSv over a 70-year projection.

- The hypothetical dose of iodine in the thyroid reached values of 2 Gy in some regions.

- The internal doses from ^{90}Sr and ^{137}Cs reached mSv unit values.

- The total dose was estimated at <1 to 170 mSv, with mean mSv unit values.

These results show that, except for doses received in the thyroid, the group of children studied received low levels of radiation doses.

6. CHARACTERISTICS OF THE BIOMEDICAL STUDIES

Biomedical studies were carried out on the children surveyed to evaluate their general health condition as well as the behaviour of the biological indicators most sensitive to the action of ionizing radiations. The evaluation was made with the aid of retrospective and prospective studies.

The overall health condition of the individuals studied and behaviour of haematological and thyroid indicators were evaluated through retrospective studies. For this purpose, the researchers used the medical diagnoses and results of the laboratory tests performed on the children as part of medical check-ups of clinical record.

General health, haemotological aspects and thyroid indicators were evaluated according to two categories, or blocs.

The first bloc was formed on the basis of the more objective results of the dosimetric studies, the ^{137}Cs body measurements. The second bloc was formed taking as reference the surface contamination level by ^{137}Cs of the places where the children came from, a criterion very much used in this kind of evaluation. Both blocs were divided into groups so that there would be a relevant number of children in each group and it would therefore be possible to establish a control or reference group.

Due to the representativity of the Ukraine sample in the dosimetric studies and the possibility this afforded to set up significant groups in both blocs, the Ukraine sample was used in the retrospective studies.

In the first bloc, 5 groups were formed (A to E) with different intervals of total measured activity of ^{137}Cs (Table XII). The principal dosimetric estimations for the groups of this first bloc appear in Table XIII. Here, Group A was considered to be the reference or control group.

In the second bloc (Table XIV), five groups (1 to 5) were formed; three with children from places with already known ^{137}Cs surface contamination levels, one with children from places evacuated and one with children from places which did not appear in the literature concerning ^{137}Cs contamination [11, 15]. The origin of each child was established through a personal questionnaire in Russian. The main dosimetric estimations for the groups of this bloc are illustrated in Table XV. Here, Group 1 was considered to be the reference or control group.

TABLE XII. BLOC I. GROUPS SET UP FOR BIOMEDICAL STUDIES

Group	Total activity interval (Bq)	Number of children (%)	Age (years)		Sex (%)	
			Average	Interval	M	F
A	<MDA	845 (28.0)	11.1	1-17	61	39
B	MDA-250	1059 (35.0)	10.7	1-20	54	46
C	250-500	602 (20.0)	11.2	1-16	53	47
D	500-1000	292 (9.7)	12.0	3-17	53	47
E	>1000	218 (7.3)	12.2	2-16	59	41

TABLE XIII. BLOC I. MAIN DOSIMETRIC CHARACTERISTICS OF THE GROUPS STUDIED (MEAN VALUES)

Group	Specific act.	External dose (mSv)		^{137}Cs internal dose (μSv)		Thyroid dose	Total dose (mSv)	
	(Bq/kg)	Study year	70 years	Study year	70 years	(mGy)	Study year	70 years
A	1.7	<1	1.5	10	20	40	2	3
B	4.4	<1	2.0	25	45	50	2	4
C	9.3	1.0	4.5	60	95	130	5	9
D	15.7	1.8	7.0	110	160	210	8	14
E	56.4	2.0	8.0	395	580	240	10	16

TABLE XIV. BLOC II. GROUPS SET UP FOR BIOMEDICAL STUDIES

Group	Surface contamination [kBq/m^2]	Number of townships	Number of children	Age (years)		Sex (%)	
				Average	Interval	M	F
1	<37	33	827 (27.4)	10.8	2-17	54	46
2	37-185	63	512 (16.9)	11.1	1-16	59	41
3	>185	19	192 (6.4)	11.4	4-17	42	58
4	evacuated	13	715 (23.8)	11.2	5-20	57	43
5	unknown	293	770 (25.5)	11.4	1-17	59	41

Group 5, made up of children whose localities did not appear in surface contamination literature, shows a broad interval of specific activity (< than MDA - 565 kBq/kg), with a low mean value. Because of this, it was believed that its composition represented children from both "clean" and contaminated areas, the former being a majority.

TABLE XV. BLOC II. MAIN DOSIMETRIC CHARACTERISTICS OF THE GROUPS STUDIED (MEAN VALUES)

Group	Cases >MDA	Specific activity	External doses (mSv)		^{137}Cs Int. doses (μSv)		Thyroid doses	Total Dose (mSv)	
	%	(Bq/kg)	Study year	70 years	Study year	70 years	(mGy)	Study year	70 years
1	65	5.6	<1	1	40	60	40	2	3
2	85	14.1	1.5	5	90	140	150	6	11
3	97	21.4	7.5	30	140	210	890	35	57
4	70	5.9	<1	1	40	60	---	<1	1
5	74	10.1	---	---	70	110	---	<1	<1

The relationship between the number of children in the groups of both blocs appears in Tables XVI and XVII.

TABLE XVI. RELATIONSHIP BETWEEN THE NUMBER OF CHILDREN IN BOTH BLOCS. FIGURES IN PER CENT IN RELATION TO GROUPS A-E

Groups	1	2	3	4	5	TOTAL
A	36.8	9.5	1.4	22.6	29.7	100
B	27.8	14.0	2.6	30.6	24.9	100
C	28.7	18.1	9.3	19.9	24.0	100
D	11.3	32.3	17.0	14.7	24.7	100
E	8.1	34.8	20.8	8.6	27.6	100

TABLE XVII. RELATIONSHIP BETWEEN THE NUMBER OF CHILDREN IN BOTH BLOCS. FIGURES IN PER CENT IN RELATION TO GROUPS 1-5

Groups	1	2	3	4	5
A	37.8	16.0	6.1	27.5	32.0
B	35.7	29.6	14.9	46.9	33.6
C	20.5	21.2	29.2	16.9	17.9
D	3.9	18.5	26.2	6.1	9.1
E	2.1	14.7	23.6	2.6	7.4
TOTAL	100	100	100	100	100

To evaluate the differences among the groups, t and χ^2 stadigraphs were used. To estimate the relationship between different parameters, the Sperkman and Pearson correlation coefficients were used.

7. HEALTH CONDITIONS OF THE SAMPLE STUDIED

7.1. INTRODUCTION

The radioepidemiological studies in the last decades of individuals exposed to ionizing radiation have contributed significantly to the scientific knowledge of the biological effects of this physical agent.

The Chernobyl nuclear accident, because of its dimension and ecological repercussions, has raised questions in the international community and speculations about its impact on the health of the population living in the areas affected by it.

The following section outlines the health status of the Ukrainian children who travelled to Cuba as part of the co-operation programme carried out on the island.

7.2. METHODOLOGY

A quantitative retrospective study was undertaken of all the diagnoses consigned in the clinical records of the children selected for biomedical studies (Section 6). Diseases were listed according to the World Health Organization classification [16].

Later, a morbidity assessment was made taking into consideration such factors as sex, age and the parameters at variance in the groups of Blocs I and II. In addition, the physical development of these children (weight and height) was observed and correlated with the chosen parameters.

7.3. MORBIDITY

Morbidity is one indicator of the health of a population. It allows to know the frequency of a disease and its distribution.

Table XVIII shows the most frequent diseases, from higher to lower frequency. Within the endocrine-metabolic diseases, the most frequent illnesses are the thyroid pathologies (99%), within the respiratory diseases, the chronic infections of the oropharynx and nasopharynx (88%), whereas in the infecto-parasitic illnesses, 89% can be traced to intestinal parasitism.

TABLE XVIII. GENERAL MORBIDITY

Diseases	No.	%
Endocrine-metabolic	1933	61.94
Haematological	1170	37.48
Respiratory	841	26.95
Symptoms-signs	672	21.53
Infecto-parasitic	451	14.45
Neurological or sense organs	405	12.90
Digestive	300	9.61
Dermatological	273	8.75
Bone, muscle and articulations	220	7.05
Congenital anomalies	215	6.89
Genital-urinary	169	5.41
Tumors	116	3.72
Mental disorders	60	1.92
Allergic and immunity disorders	28	0.80
Circulatory	25	0.80
Traumas	13	0.42
Nutritional	2	0.06
Perinatal complications	1	0.03

Table XIX shows morbidity indicators according to sex and age. As can be seen, morbidity is higher in females in almost all the pathologies and in the 10- to 15- year-old age group.

These results are in agreement with the criteria used in the sample selection and do not point to a special vulnerability of these groups.

TABLE XIX. MORBIDITY ACCORDING TO SEX AND AGE (FIGURES IN PER CENT)

	Sex		Ages			
Diseases	Males	Females	0-5	5-10	10-15	15-20
Endocrine-metabolic	41.54	58.45	0.98	30.99	67.41	0.62
Haematological	45.24	54.75	1.54	35.65	62.30	0.51
Respiratory	45.06	54.93	2.14	33.89	63.61	0.36
Symptoms-signs	39.58	60.41	1.93	31.40	66.52	0.15
Infecto-parasitic	42.35	57.60	3.33	38.80	57.65	0.22
Neurological or sense organs	40.00	60.00	1.73	27.16	70.12	0.99
Digestive	37.66	62.33	2.00	27.67	70.33	-
Dermatological	35.53	64.46	2.20	29.30	68.13	0.37
Bone, muscle and articulations	42.27	57.72	3.18	26.82	70.00	-
Congenital anomalies	45.58	54.41	3.26	28.84	67.91	-
Genital-urinary	74.55	25.44	3.55	39.05	57.40	-
Tumors	44.82	53.17	2.59	22.41	74.14	0.86
Mental disorders	53.33	46.66	3.33	48.33	48.33	-
Allergic and immunity disorders	50.00	50.00	14.29	35.71	50.00	-
Circulatory	36.00	64.00	-	32.00	68.00	-
Traumas	69.23	30.76	-	38.46	61.54	-
Nutritional	50.00	50.00	-	50.00	50.00	-
Perinatal complications	--	100	-	100	-	-

Tables XX and XXI show the morbidity in the groups of Blocs I and II. The most significant element in these tables is the increase in the endocrine-metabolic diseases in both blocs and the higher frequency of the first eleven groups of diseases in Group 4 (evacuated children).

TABLE XX. BLOC I. MORBIDITY (FIGURES IN PER CENT).

	Groups				
Diseases	A	B	C	D	E
Endocrine-metabolic	51.25	60.09	68.52	74.00	79.19
Haematological	31.52	40.81	40.46	38.67	33.48
Respiratory	19.61	29.77	30.67	29.67	28.05
Symptoms-signs	16.89	23.62	22.19	25.33	22.62
Infecto-parasitic	13.72	17.19	11.26	10.67	17.65
Neurological or sense organs	11.90	13.39	13.87	10.67	15.84
Digestive	8.28	10.50	10.77	8.33	9.05
Dermatological	8.84	7.96	6.69	12.00	13.57
Bone, muscle and articulations	5.56	7.15	8.16	7.00	9.50
Congenital anomalies	6.92	6.43	7.01	7.33	8.14
Genital-urinary	4.20	6.24	6.85	4.00	4.07
Tumors	3.17	3.71	4.24	5.00	2.71
Mental disorders	2.38	1.90	1.96	1.00	1.36
Allergic and immunity disorders	0.23	1.36	0.98	1.33	0.45
Circulatory	0.11	0.90	0.65	2.00	1.81
Traumas	0.45	0.45	0.49	0.33	-
Nutritional	0.23	-	-	-	-
Perinatal complications	-	-	0.16	-	-

TABLE XXI. BLOC II. MORBIDITY (FIGURES IN PER CENT)

	Groups				
Diseases	1	2	3	4	5
Endocrine-metabolic	57.33	65.27	66.15	69.43	57.02
Haematological	38.02	35.69	32.82	43.98	33.09
Respiratory	28.72	22.14	25.64	32.23	23.81
Symptoms-signs	17.21	21.76	21.54	31.54	17.09
Infecto-parasitic	12.79	12.60	14.36	17.43	14.77
Neurological or sense organs	12.67	11.83	11.79	16.74	10.99
Digestive	10.00	7.82	6.67	18.65	10.13
Dermatological	7.56	8.59	6.67	10.65	8.91
Bone, muscle and articulations	7.33	6.68	8.21	8.71	5.25
Congenital anomalies	6.40	6.30	7.18	8.02	6.72
Genital-urinary	6.51	4.39	3.59	7.47	3.54
Tumors	3.37	4.01	2.56	3.87	4.03
Mental disorders	2.21	3.24	2.05	1.80	0.85
Allergic and immunity disorders	1.16	0.76	1.03	0.97	0.61
Circulatory	0.47	1.34	3.08	0.41	0.61
Traumas	0.58	0.38	1.03	0.41	0.12
Nutritional	0.12	-	-	0.14	-
Perinatal complications	0.12	-	-	-	-

7.4. GROWTH AND DEVELOPMENT

The anthropometric measurements of a population are important indicators of their health and nutritional status. The environment is one of the factors that influences these values.

In Table XXII, the mean values of weight and height increase in direct relation to age for both sexes. The mean values are higher in males, except for the 10- to 15-year-old age group, where girls normally weigh more than boys.

TABLE XXII. WEIGHT AND HEIGHT INDICATORS ACCORDING TO SEX AND AGE. MEAN VALUES ± S.D.

	Weight (kg)		Height (cm)	
Ages	Males	Females	Males	Females
0-5	20.31 ± 9.86	18.63 ± 6.35	106.28 ± 24.81	103.01 ± 21.27
5-10	31.60 ± 7.25	31.21 ± 7.53	134.73 ± 11.22	134.54 ± 12.57
10-15	45.62 ± 11.19	48.01 ± 24.83	154.14 ± 12.86	154.25 ± 10.24
15-20	62.30 ± 20.26	56.56 ± 10.15	165.67 ± 15.34	161.45 ± 5.44

Tables XXIII, XXIV, XXV and XXVI show the behaviour of the weight and height in Blocs I and II. Such tables confirm the absence of weight and height differences for the groups included in both blocs.

TABLE XXIII. BLOC I. WEIGHT INDICATORS. MEAN VALUES ± S.D.

	Males Weight (kg)/ages			
Groups	0-5	5-10	10-15	15-20
A	23.69 ± 16.39	30.48 ± 5.66	46.50 ± 12.40	79.00 ± 0.00
B	20.38 ± 6.05	30.60 ± 6.31	43.65 ± 10.17	51.25 ± 31.04
C	16.60 ± 4.28	32.19 ± 7.40	43.98 ± 9.70	--
D	16.10 ± 0.00	35.37 ± 10.25	47.56 ± 11.03	--
E	16.00 ± 0.00	40.51 ± 12.66	50.59 ± 13.51	61.30 ± 0.00
	Females Weight (kg)/ages			
Groups	0-5	5-10	10-15	15-20
A	18.17 ± 4.64	30.90 ± 6.81	48.49 ± 10.75	48.83 ± 5.03
B	20.45 ± 9.09	30.09 ± 7.86	45.23 ± 26.65	57.50 ± 12.73
C	17.20 ± 3.35	32.02 ± 6.83	48.32 ± 31.61	65.67 ± 16.24
D	--	36.31 ± 9.78	52.49 ± 37.98	55.15 ± 6.73
E	--	34.11 ± 7.39	51.74 ± 13.24	48.00 ± 0.00

TABLE XXIV. BLOC I. HEIGHT INDICATORS. MEAN VALUES ± S.D.

	Males Height (cm)/ages			
Groups	0-5	5-10	10-15	15-20
A	106.33 ± 37.48	134.09 ± 10.70	155.09 ± 12.71	177.00 ± 8.00
B	112.17 ± 15.20	133.77 ± 12.59	152.98 ± 11.34	155.00 ± 21.21
C	101.08 ± 15.42	135.08 ± 9.06	152.47 ± 13.68	-
D	97.50 ± 0.00	137.11 ± 9.44	155.78 ± 11.24	-
E	105.00 ± 0.00	143.85 ± 9.44	155.86 ± 18.13	162.00 ± 0.00
	Females Height (cm)/ages			
Groups	0-5	5-10	10-15	15-20
A	103.83 ± 19.10	133.90 ± 11.84	155.21 ± 13.43	177.00 ± 0.00
B	107.85 ± 20.53	133.69 ± 12.77	152.86 ± 8.69	162.00 ± 10.61
C	100.20 ± 21.11	135.86 ± 9.36	153.84 ± 9.09	167.07 ± 5.18
D	-	137.30 ± 8.79	155.21 ± 7.76	157.50 ± 2.65
E	-	138.74 ± 7.57	156.12 ± 9.40	158.00 ± 0.00

TABLE XXV. BLOC II. WEIGHT INDICATORS. MEAN VALUES ± S.D.

	Males Weight (kg)/ages			
Groups	0-5	5-10	10-15	15-20
1	18.17 ± 4.23	31.04 ± 6.64	45.36 ± 11.43	78.07 ± 4.47
2	21.76 ± 10.83	32.99 ± 9.85	45.56 ± 10.70	-
3	21.00 ± 1.41	30.77 ± 6.21	46.27 ± 11.02	-
4	26.86 ± 19.67	32.62 ± 7.53	47.49 ± 12.42	29.30 ± 0.00
5	17.93 ± 2.75	30.68 ± 5.78	44.11 ± 9.99	55.15 ± 8.70
	Females Weight (kg)/ages			
Groups	0-5	5-10	10-15	15-20
1	16.20 ± 3.53	31.04 ± 7.34	47.60 ± 29.58	62.47 ± 19.10
2	20.14 ± 3.42	32.77 ± 8.49	46.34 ± 11.59	48.30 ± 0.00
3	-	32.13 ± 7.68	46.11 ± 10.21	55.08 ± 6.83
4	25.67 ± 12.27	31.43 ± 7.44	49.63 ± 27.76	48.50 ± 0.00
5	17.77 ± 2.94	29.81 ± 6.85	48.31 ± 25.69	57.32 ± 8.04

7.5. CONCLUSIONS

The primary objective of the medical assistance programme carried out in Cuba on children from the zones affected by the Chernobyl accident was to search actively for indications of pathology. Therefore, and given the wealth of information available on the biological effects of ionizing radiation in the literature, no association should be drawn between the findings of the programme and the exposure levels to which the children were submitted.

The results of these findings can be explained by the criteria used in the selection of the sample and by the morbidity prevailing in the regions where the children live.

TABLE XXVI. BLOC II. HEIGHT INDICATORS. MEAN VALUES ± S.D.

Groups	Males Height (cm)/ages			
	0-5	5-10	10-15	15-20
1	100.18 ± 30.41	135.23 ± 9.66	154.69 ± 11.53	177.00 ± 7.00
2	110.30 ± 27.93	135.21 ± 9.80	153.37 ± 14.31	-
3	118.00 ± 0.00	136.47 ± 8.99	154.37 ± 12.15	-
4	119.44 ± 25.47	133.78 ± 15.38	156.74 ± 12.70	140.00 ± 0.00
5	101.32 ± 17.36	133.97 ± 9.62	151.76 ± 13.17	161.50 ± 0.71
Groups	Females Height (cm)/ages			
	0-5	5-10	10-15	15-20
1	93.41 ± 21.70	133.93 ± 12.84	154.76 ± 9.00	165.17 ± 5.75
2	110.00 ± 3.74	134.69 ± 15.26	152.46 ± 8.97	159.00 ± 0.00
3	-	137.19 ± 10.06	153.07 ± 10.70	157.25 ± 2.50
4	119.58 ± 32.03	134.88 ± 8.95	155.48 ± 10.74	154.50 ± 0.00
5	105.90 ± 7.29	134.53 ± 13.35	154.08 ± 11.17	163.95 ± 5.00

8. BEHAVIOUR OF THE PRINCIPAL HAEMATOLOGICAL INDICATORS

8.1. INTRODUCTION

The haemopoietic system is highly sensitive to the action of ionizing radiations. Changes produced by these radiations on the peripheral haemogram have been well documented in men. The main data sources have been patients subjected to radiotherapy, people involved in accidents or survivors of atomic bombings [14, 17].

International expert groups and local specialists have examined the behaviour of the peripheral haemogram in people living in areas affected by the Chernobyl accident to assess overall health conditions and their influence on the area's existing radioecological conditions. The main hurdles in interpreting results are the absence or scarcity of data concerning the situation before the accident and the difficulty of obtaining data from populations with different characteristics [11].

This section examines the behaviour of the peripheral haemogram performed routinely on the children cared for in Cuba.

8.2. METHODOLOGY

The haematological indicators examined in the study were haemoglobin, haemocytes and leucocytes, eosinophils, monocytes, polymorphs and lymphocytes absolute count.

Haemoglobin was automatically determined through a haemoglobinometer. The cell count was done by microscope. The values shown in Table XXVII were considered normal.

TABLE XXVII. NORMAL INTERVALS OF EXAMINED HAEMATOLOGICAL INDICATORS

Indicator	Unit	Normal interval
Haemoglobin	g/L	>110 - 130 (under 6 years) >120 - 140 (over 6 years)
Haemocytes	vol.%	0.40 - 0.50 (males) 0.38 - 0.47 (females)
Leucocytes	N° x 10^9/L	5 - 10
Polymorphs	%	0.55 - 0.65
Lymphocytes	%	0.25 - 0.40
Eosinophils	%	0.01 - 0.05
Monocytes	%	0.03 - 0.05

8.3. RESULTS AND DISCUSSION

The behaviour of haematological values with respect to normal values is shown in Tables XXVIII and XXIX. Tables XXX and XXXI show mean values with their standard deviation.

TABLE XXVIII. BLOC I. BEHAVIOUR OF HAEMATOLOGICAL INDICATORS WITH RESPECT TO NORMAL VALUES (FIGURES IN PER CENT)

Group	Haemoglobin			Haemocytes				Leucocytes				Eosinophils		
	low	normal	NA*	low	normal	high	NA*	low	normal	high	NA*	normal	high	NA*
A	13 0	86 7	0 2	15 9	70 3	0 9	12 9	2 1	91 4	5 9	0 6	63 7	26 3	10 0
B	12 6	87 1	0 3	18 7	70 2	0 9	10 3	3 0	91 5	5 1	0 4	64 9	23 1	12 0
C	12 0	87.5	0 5	20 1	70 1	0 5	9 3	4 5	90 5	5 0	0 0	65 1	22 7	12 1
D	6 8	92 8	0 3	14 0	76 4	0 3	9 2	3 8	92 1	4 1	0 0	66 4	22 6	11 0
E	7 8	91 3	0 9	11 5	74 8	0 4	13 3	3 2	95 4	0 9	0 4	60 1	30 7	9 1

* NA= No information available

TABLE XXVIII. (cont.)

Group	Monocytes				Polymorphs				Lymphocytes			
	low	normal	high	NA*	low	nor-mal	high	NA*	low	normal	high	NA*
A	38 6	18 1	5 7	37 6	64 6	25 9	9 3	0 1	4,8	32 5	62 2	0 3
B	34 8	19 1	5 8	40 3	60 3	28 0	11 4	0 2	6 0	36 6	56 7	0 6
C	38 9	19 3	5 1	36 7	62 1	27 6	10 1	0 2	4 6	36 7	58 5	0 2
D	34 0	23 0	3 7	39 3	62 0	28 8	9 2	0 0	3 8	36 3	59 6	0 3
E	32 1	18 3	3 2	46 3	61 9	27 1	11 0	0 0	2 7	33 0	58 2	0 0

* NA= No information available.

TABLE XXIX. BLOC II. BEHAVIOUR OF HAEMATOLOGICAL INDICATORS WITH RESPECT TO NORMAL VALUES (FIGURES IN PER CENT)

Group	Haemoglobin			Haemocytes				Leucocytes				Eosinophils		
	low	normal	NA*	low	normal	high	NA*	low	normal	high	NA*	normal	high	NA*
1	16 7	83 1	0 2	20 3	68 9	0 9	9 8	3 1	91 4	4 9	0 5	63 6	24 1	12 3
2	12 3	87 3	0 4	14 4	71 9	0 8	12 9	2 7	93 8	2 9	0 6	63 3	26 4	10 3
3	9 9	87 5	2 6	15 6	75 5	0 0	8 9	2 1	93 2	4 7	0.0	56 3	25 5	18 2
4	15 1	84 3	0 6	15 5	72 7	0 4	11 3	4 0	89 5	6 0	0 4	69 5	19 4	11 3
5	15 6	84 0	0 4	17 4	69 7	0 9	11 9	2 8	91 2	5 0	0 9	62 7	27 6	9 6

* NA= No information available

TABLE XXIX. (cont.)

Group	Monocytes				Polymorphs				Lymphocytes			
	low	normal	high	NA*	low	normal	high	NA*	low	normal	high	NA *
1	36 7	24 4	1 5	37 2	63 5	25 3	11 0	0 2	4,8	34 6	60 0	0 5
2	37 3	25 0	1 0	36 7	62.3	28 7	8 4	0 6	2 5	39 5	57 4	0 6
3	33 3	20 3	2 1	44 3	66 1	24 5	9 4	0 0	4 7	33 3	61 5	0 5
4	35 4	23 8	0 8	40 0	56 9	29 6	13 4	0 0	8 0	34 7	56 6	0 7
5	36 5	21 8	0 1	41 2	63 9	26 9	8 4	0 8	4 0	35 6	59 7	0 6

* NA= No information available

TABLE XXX. BLOC I. MEAN VALUES ± STANDARD DEVIATION OF HAEMATOLOGICAL INDICATORS

Group	Haemoglobin g/L	Haemocytes vol %	Leucocytes %	Eosinophils %	Monocytes %	Polymorphs %	Lymphocytes %
A	128 58±12 80	0 41±0 04	6 97±1 73	0 05±0 05	0 03±0 03	0 51±0 11	0 44±0 18
B	128 39±13 94	0 40±0 03	7 09±3 14	0 04±0 05	0 03±0 02	0 53±0 26	0 42±0 11
C	128 68±10 11	0 40±0 03	6 89±1 63	0 04±0 04	0 03±0 03	0 52±0 10	0 43±0 10
D	130 21±8 43	0 41±0 02	7 13±4 03	0 04±0 03	0 03±0 02	0 52±0 10	0 43±0 10
E	131 35±9 26	0 41±0 03	6 80±1 39	0 05±0 03	0 02±0 02	0 52±0 11	0 43±0 10

TABLE XXXI. BLOC II. MEAN VALUES ± STANDARD DEVIATION OF HAEMATOLOGICAL INDICATORS

Group	Haemoglobin g/L	Haemocytes vol %	Leucocytes %	Eosinophils %	Monocytes %	Polymorphs %	Lymphocytes %
1	128 70 ± 11 47	0 40 ± 0 03	7 01 ± 3 40	0 05 ± 0 05	0 03 ± 0 03	0 52 ± 0 24	0 43 ± 0 18
2	129 22 ± 10 37	0 41 ± 0 04	6 94 ± 3 21	0 04 ± 0 03	0 03 ± 0 02	0 52 ± 0 10	0 43 ± 0 10
3	131 02 ± 8 94	0 41 ± 0 04	6 95 ± 1 58	0 11 ± 0 88	0 03 ± 0 03	0 51 ± 0 10	0 43 ± 0 11
4	128 12 ± 15 53	0 41 ± 0 03	7 08 ± 1 77	0 04 ± 0 05	0 04 ± 0 29	0 53 ± 0 11	0 42 ± 0 11
5	128 67 ± 12 58	0 41 ± 0 03	6 95 ± 1 69	0 05 ± 0 04	0 02 ± 0 02	0 52 ± 0 20	0 43 ± 0 10

The best behaviour of haemoglobin and haemocytes is found in Groups D and E from Bloc I and Group 3 from Bloc II.

In the areas affected by the Chernobyl accident, the evidence of anaemia and its degree of diffusion is not clear. Before the accident, the data covered sick people in general, and very rarely asymptomatic people. According to data offered to the expert group of the International Chernobyl Project (ICHP) by specialists of institutions in Moscow, 8 to 12% of the entire population of the former USSR is anaemic; in children under the age of seven, the percentage is as high as 30. According to the source, 5 to 12% of Kiev's paedriatic population is anaemic. And, according to Ukraine specialists, anaemia affects 10% of the adults and 30% of the children in the former USSR [11].

In the group of 296 children of a similar age from several locations examined as part of the ICHP, the percentage of cases with haemoglobin levels under those we considered normal fluctuated between 5.19 and 13.15. Differences among "clean" and contaminated regions were not significant. These data suggest that the existence of anaemia is not linked to the area's radioecological conditions nor to the restrictions caused by them.

Leucopenia levels varied from near 4% (Groups C and 4) to 2% (Groups A and 3). According to reports sent to the ICHP [11], 5 to 7% of the children suffer from leucopenia, lymphopenia or transitory thrombocytopenia, which generally disappears when they are hospitalized for supplementary tests. The transitional nature of these changes has been associated with environmental problems or with the values of parameters in lower normality levels. Comparative studies made in control and contaminated areas have not shown significant differences between them [11]. The results of this study do not show trends among the groups with different characteristics.

A high percentage of cases with high lymphocyte levels and low polymorph levels is present in all groups. The mean values for these indicators show alterations. These findings cannot be explained by the age structure of the sample studied, since lymphocytes did not predominate in the white blood cell count of the older segment of individuals surveyed [17]. Lymphocytes are highly sensitive to ionizing radiation and for that reason, their levels drop in the presence of given threshold doses. Here, the abnormal behaviour of lymphocytes and polymorphs is associated with infection. The behaviour of the white blood cells is statistically significant ($p < 0.001$), as 54-56% of the individuals diagnosed with infecto-parasitic, haematological, digestive, respiratory and genital-urinary diseases display high lymphocyte and low polymorph levels. The presence of "lymphoid hyperplasia", characterized by an association of mild lymphocytosis and a hypertrophy of the lymphoid structures, which was observed in some 54-60% of the digestive, respiratory and ganglionic anatomic locations of the individuals studied, may also support this lymphocitic behaviour.

Eosinophilia, detected in almost 24% of the individuals studied, is statistically significant ($p < 0.001$) with regard to immunoallergic (29%) and parasitic (39%) diseases.

8.4. CONCLUSIONS

The data obtained suggest that internal contamination by ^{137}Cs or restrictions due to the area's radioecological conditions did not produce detectable haematological changes within the set of disorders attributable to other aetiological factors.

9. BEHAVIOUR OF THE PRINCIPAL THYROID INDICATORS

9.1. INTRODUCTION

Thyroid disorders in people from areas affected by the Chernobyl accident are of interest to specialists throughout the world.

The thyroid gland can actively concentrate iodine. For this reason, it was the organ most affected during the accident [19, 20]. The thyroid is considered radio-resistant and the location where late deterministic effects occur, the most common of them being hypothyroidism [14, 21].

9.2. METHODOLOGY

The indicators taken into account to assess the condition of the thyroid were tiroxine hormone levels (T4), thyroid stimulant hormone (TSH) and a clinical diagnosis of thyroid hyperplasia.

Hormones T4 and TSH were determined through the ultra-micro-analytic system (SUMA) that uses automated detection based on immune-enzymatic processes. The values considered normal were those used in national medical practice, that is, 45-150 nM/L for T4 and 0-7 mU/mL for TSH. The presence and level of hyperplasia were determined through palpation by a team of senior endocrinologists.

The groups studied and their main dosimetric characteristics are detailed in Tables XII to XV. The methodology and criteria used to organize blocs, groups and collect results are explained in Section 6.

9.3. RESULTS AND DISCUSSION

Tables XXXII and XXXIII highlight the behaviour of hormones T4 and TSH compared with normal values. In Bloc I, the percentage of cases with high TSH figures ranges from 0 (Group C) to 1.2 (Group D), while in Bloc II, it ranges from 0 (Group 2) to 1.3 (Group 1). The radioecological conditions in the zones where the children live have not caused an increase of cases with high TSH figures.

TABLE XXXII. BLOC I. BEHAVIOUR OF T4 AND TSH COMPARED WITH NORMAL VALUES (FIGURES IN PER CENT)

Group	T4			Group	TSH	
	Low	Normal	High		Normal	High
A (494)*	1.2	82.6	16.2	A (559)	99.1	0.9
B (613)	0.3	81.0	18.7	B (563)	99.1	0.9
C (362)	0.0	86.2	13.8	C (343)	100.00	0.00
D (179)	1.1	77.1	21.8	D (164)	98.8	1.2
E (133)	0.0	73.7	26.3	E (127)	99.2	0.8
Total (1781)	0.6	81.5	17.9	Total (1756)	99.3	0.7

* Figures in parenthesis: total number of individuals tested for hormone determination in each group.

The ICHP found that 1% of the cases it studied had high TSH levels in the control and contaminated areas. In 1987-1988, Ukraine specialists reported an inverse relationship between doses levels and high TSH (11% of cases with high TSH in "clean" areas and 5% in children with thyroid doses over 5 Gy).

TABLE XXXIII. BLOC II. BEHAVIOUR OF T4 AND TSH COMPARED WITH NORMAL VALUES (FIGURES IN PER CENT)

Group	T4			Group	TSH	
	Low	Normal	High		Normal	High
1 (460)*	1.1	83.7	15.2	1 (470)	98.7	1.3
2 (332)	0.3	76.8	22.9	2 (320)	100.0	0.0
3 (90)	0.0	86.7	13.3	3 (96)	99.0	1.0
4 (397)	0.0	86.6	19.4	4 (306)	99.7	0.3
5 (502)	0.8	82.5	16.7	5 (564)	99.1	0.9
Total (1781)	0.6	81.5	17.9	Total (1756)	99.3	0.7

* Figures in parenthesis: total number of individuals tested for hormone determination in each group.

Our data indicate that the main thyroid function anomaly in the groups studied is associated with an increase in T4 with respect to normal values. In Bloc I, the increase ranges from 13.8% (Group C) to 26.3% (Group E), with a statistically not significant general tendency ($p > 0.05$) towards a high number of cases with high T4 in subgroups A to E. In Bloc II, the increase ranges from 13.3% (Group 3) to 22.9% (Group 2). No trend was observed in Groups 1 to 5. In both control groups, figures are similar (15-16%). Ukrainian specialists reported that up to 18% of the children from the control areas had a high T4, compared with 30-40% of the children with doses in thyroids higher than 0.3 Gy, 35% with doses ranging between 0.31-1.0 Gy and 29% with doses higher than 5.0 Gy [11]. In the contaminated and control areas studied by the ICHP, there were no significant differences found (2% in contaminated areas and 7% in the control groups).

The dates consulted in the literature do not allow to establish any relationship between dose and T4 increase. In our data, the only factor that seems to bear a relationship with the increase of cases with T4 values above normal are the measurements of ^{137}Cs; however, the correlation is not statistically significant ($p > 0.05$).

Following damage to thyroid cells, there is usually a decrease in thyroid hormone levels, an increase in TSH and a return to normality or decrease in T4 levels. The results observed do not indicate this trend. Nor is it observed when examining mean T4 and TSH values. (Tables XXXIV and XXXV.)

TABLE XXXIV. BLOC I. MEAN VALUES (M) AND STANDARD DEVIATION (S.D.) OF HORMONES T4 AND TSH

Group	TSH		T4	
	Number of cases	M ± S.D.	Number of cases	M ± S.D
A	559	1.7 ± 2.4	494	118.6 ± 51.1
B	563	1.5 ± 1.6	613	116.5 ± 38.4
C	343	1.4 ± 1.1	362	111.8 ± 41.1
D	164	1.5 ± 1.6	179	120.3 ± 68.8
E	127	1.3 ± 1.7	133	123.9 ± 40.9

TABLE XXXV. BLOC II. MEAN VALUES (M) AND STANDARD DEVIATION (S.D.) OF HORMONES T4 AND TSH

Group	TSH		T4	
	Number of cases	M ± S.D.	Number of cases	M ± S.D.
1	470	1.7 ± 2.7	460	114.8 ± 51.5
2	320	1.5 ± 1.4	332	121.2 ± 41.2
3	96	1.2 ± 1.1	90	109.9 ± 37.8
4	306	1.4 ± 1.3	397	118.1 ± 40.2
5	564	1.5 ± 1.6	502	116.9 ± 51.3

An analysis of the simultaneous behaviour of both hormones (Tables XXXVI and XXXVII) shows that normal TSH values are accompanied by normal T4 values in 82% of the cases. A reduction of T4 with TSH values below normality only occurs in 0.6% of the cases. Some 17% show a high T4 with a normal TSH.

Several studies have shown that hypothyroidism is dose dependent. The data presently available are not sufficient to define threshold doses higher than 1 Gy [21]. In the present study, the estimated mean doses to the thyroid are below this value and have not given rise to hypothyroidism.

The high prevalence of infection, associated with the behaviour of the leucocyte count and high T4 values, could suggest that the reason for this hormonal behaviour may be associated with a thyroiditis infection of an immunological nature.

Tables XXXVIII and XXXIX show the percentages of cases with thyroid hyperplasia and their degrees. Here, a statistically significant increase ($p < 0.001$) in the rates of hyperplasia can be observed in Groups A to E and 1 to 4. The internal contamination by ^{137}Cs and the estimated dose to the thyroid increase in Groups A to E, while groups 1 to 4 differ, owing to the radioecological conditions in the townships at the time of the accident. The estimated thyroid doses are higher in groups 1 to 3, but were not estimated in Group 4. Measurements of ^{131}I taken on individuals evacuated from Pripyat show that 97% of them received thyroid doses below 0.3 Gy [20], and therefore it does not necessarily follow that persons evacuated received doses higher than those calculated for persons living in townships included in Group 3. The estimated thyroid doses are four times higher for Group 3 than those of Group E, while the hyperplasia frequencies are 66% in Group 3 and 77% in E (statistically significant $p < 0.001$). Based on these observations, it is not possible to establish a direct relationship between estimated thyroid dose and hyperplasia frequency.

TABLE XXXVI. BLOC I. SIMULTANEOUS BEHAVIOUR OF T4 AND TSH COMPARED WITH NORMAL VALUES

Group	NORMAL TSH			HIGH TSH		
	T4 low	T4 normal	T4 high	T4 low	T4 normal	T4 high
A (440)	1.4	83.4	14.5	0.0	0.5	0.2
B (528)	0.4	80.7	17.9	0.0	0.8	0.2
C (323)	0.0	88.2	11.8	0.0	0.0	0.0
D (161)	0.6	75.8	22.4	0.0	1.2	0.0
E (123)	0.0	72.4	26.8	0.0	0.8	0.0
Total (1575)	0.6	81.8	16.9	0.0	0.6	0.1

* Figures in parentheses: total cases with determination of both hormones in each group.

TABLE XXXVII. BLOC II. SIMULTANEOUS BEHAVIOUR OF T4 AND TSH COMPARED WITH NORMAL VALUES

Group	NORMAL TSH			HIGH TSH		
	T4 low	T4 normal	T4 high	T4 low	T4 normal	T4 high
1 (422)	1.2	84.1	13.5	0.0	1.2	0.0
2 (291)	0.3	76.6	23.1	0.0	0.0	0.0
3 (86)	0.0	86.0	14.0	0.0	0.0	0.0
4 (300)	0.0	81.4	18.3	0.0	0.3	0.0
5 (476)	0.6	82.6	15.8	0.0	0.6	0.4
Total (1575)	0.6	81.8	16.9	0.0	0.6	0.1

* Figures in parentheses: total cases with determination of both hormones in each group.

TABLE XXXVIII. BLOC I. FREQUENCY OF THYROID HYPERPLASIA (FIGURES IN PER CENT)

Group	Degree of hyperplasia				% of cases with hyperplasia
	IA	IB	II	III	
A	31.63	15.19	3.58	0.23	50.91
B	34.75	18.01	6.33	0.36	59.37
C	43.07	17.29	7.18	0.49	68.03
D	43.00	20.67	8.00	1.33	73.00
E	32.58	27.60	15.84	1.36	77.38
Total	36.20	18.00	6.60	0.51	61.29

TABLE XXXIX. BLOC II. FREQUENCY OF THYROID HYPERPLASIA (FIGURES IN PER CENT)

Group	Degree of hyperplasia				% of cases with hyperplasia
	IA	IB	II	III	
1	35.47	15.58	5.35	0.35	56.74
2	33.78	20.61	8.97	0.57	63.93
3	37.44	18.46	9.23	1.03	66.15
4	41.91	20.47	6.50	0.00	68.74
5	32.97	16.61	5.98	0.98	56.53
Total	36.20	18.00	6.60	0.51	61.29

Hyperplasia is present in 61% of the cases in this study. Ninety per cent of the hyperplasias are of degree IA (66%) or IB (30%).

According to data presented to the ICHP by Ukraine sources, the prevalence of hyperplasia in the Narodichi district between 1986 and 1988 was from 20% to 40%, unrelated to doses in the thyroid. In areas of Belarus, 40% of the children had hyperplasia degree I and 3-4% degrees II and III. Hyperplasia prevalence in the Russian region of Briansk was 75% in children 6 to 10 years old and 85% in children 10 to 15. In this group, 41% of hyperplasias were degree I, 28% degrees I and II, 25% degree II and 6% degree III [11]. In children aged 5 to 10, the ICHP found 0.5% of the hyperplasia cases in contaminated areas and 7.5% in control areas.

The high percentages of hyperplasia found in the present study may be associated with selection processes.

9.4. CONCLUSIONS

- The main anomaly observed in the function of the thyroid in the groups studied is an increase in T4 values over normal values.

- Thyroid hyperplasias tend to arise more frequently as the internal contamination from ^{137}Cs and the surface contamination of the territories where the children were located at the time of the accident increase. This trend is not associated with the estimated thyroid doses.

10. CYTOGENETIC STUDIES

10.1. INTRODUCTION

The biological indicators most sensitive to ionizing radiation are cytogenetic. They have been recognized as biological dosimeters in cases of serious radiation exposure [22], it being possible to detect doses up to 100 mSv when a sufficient quantity of metaphases are analyzed. In the study of individuals chronically exposed to radiations due to their occupation or because they live in a highly radioactive background, cytogenetic studies have been used to characterize the influence of such conditions [23].

10.2. METHODOLOGY

The indicators used were the frequency of chromosome aberrations and micronuclei on peripheral blood lymphocytes.

Cell culture and processing were made through standardized methods in the Radiobiology laboratory. For the obtention of metaphases, 1 ml of blood was used. This was inoculated in 9 ml of a culture mixture containing: RPMI-1640 medium supplemented with a 10% fetal calf serum, 400 units of penicillin G, 400 μg of Streptomycin sulphate and 200 μl of phytohaemagglutinin HA-15 Wellcome. Colchicine was added to this culture up to a final concentration of 0.4 μg/ml, three hours before ending the 48-hours of incubation at 37°C [24]. Cells were processed with a hypotonic solution (0.075 M KCL) and fixed with methanol-acetic acid (3:1).

To obtain binucleated lymphocytes, the same proportion of blood and culture mixture was used but with volumes reduced 4 times. The incubation time was 69 hours at 37 °C. After 44 hours, cytochalasin B was added to a final concentration of 6 μg/ml. Cells were processed without hypotonic treatment and directly with a fixative [25]. Cases were considered useful where it was possible to examine 130-500 metaphases and 300-500 binucleated lymphocytes. Dicentric values between 0 and 0.1 and micronuclei values between 0 and 0.8 per one hundred cells were taken as normal.

Children from Kiev, Ovruch, and Pripyat were selected for the study as representative for our sample of inhabitants of areas evidencing various degrees of background radioactivity. Kiev ("clean") showed soil contamination values due to ^{137}Cs under 37 kBq/m^2 [11], Ovruch (affected by higher background radioactivity levels) displayed a high transfer coefficient of ^{137}Cs, while Pripyat was evacuated shortly after the accident due to worsened radiological conditions in the township.

Sixty-nine children were examined. Table XL breaks down their number by location, age and sex.

TABLE XL. CHARACTERISTICS OF GROUPS SELECTED FOR CYTOGENETIC STUDIES

Location	Number of cases studied	Sex		Age (years)	
		M	F	Interval	Average
Ovruch	20	10	10	8-14	12.5
Pripyat	28	19	9	8-14	10.5
Kiev	21	8	13	7-15	11.4

10.3. RESULTS AND DISCUSSION

Table XLI shows the results obtained. The frequency of the indicators studied falls within the normal ranges of the three locations selected. Total acentric and aberration frequencies are significantly ($p < 0.05$) higher in individuals from the control location (Kiev) than in those from other locations, mainly due to the presence of three cases with high acentric frequencies. The frequency of micronuclei is higher in subjects from Ovruch than from Kiev, although both groups fall within normal intervals of low values, which are to be associated with the age of the individuals.

TABLE XLI. RESULTS OF THE CYTOGENETIC STUDIES

Location	Number of metaphases examined	Frequency/100 cells				Number of lymphocytes	Frequency micronucl./ 100 cells
		Acentric	Dicentric	Rings	Totals		
Ovruch	2779	0.18 ± 0.08	0.03 ± 0.03	0.0	0.22 ± 0.09	9891	0.87 ± 0.09
Pripyat	11475	0.35 ± 0.05	0.02 ± 0.01	0.0	0.37 ± 0.06	13500	0.56 ± 0.06
Kiev	5406	0.60 ± 0.10	0.04 ± 0.03	0.0	0.66 ± 0.11	13954	0.60 ± 0.06

The results obtained from the cytogenetic studies of individuals not acutely exposed to the Chernobyl radiations are contradictory. No significant differences were found between adults from contaminated areas who must have received higher radiation doses since they worked in the open, and adults of similar age working in the open in 'clean' areas where radiation doses can be traced to the environmental background. Chromosomal aberration frequencies — particularly dicentric — were comparatively high, well above normal [11]. Specialists from affected territories differ over these results and state that in the areas they studied, chromosomal aberration frequencies were higher among people from contaminated townships [26, 27].

Cytogenetic studies performed on foreigners who had been in areas close to the accident and who were evacuated to their respective countries in its aftermath revealed the presence of dicentric figures. These were found to be higher than normal, but bear no relationship with the radiation doses they received [28] or lie within normal values based on the doses estimated [29]. There were no dicentric or total chromosomal aberration frequencies above normal in 50 children from Pripyat [30]. Another study on 102 adults evacuated from Pripyat shows cell frequencies with chromosomal aberrations above normal levels [31].

The areas affected by the Chernobyl accident are extensive. The radioecological conditions of the towns and the radiation doses received by their population vary from case to case. Estimates put them in the order of mSv in the four years following the accident. With such values, received chronically, a significant increase of chromosomal aberration levels is not to be expected.

10.4. CONCLUSIONS

- No instances were found of high frequencies of chromosomal aberration nor of micronuclei potentially induced by radiations.

- Dicentric frequencies in the three locations studied fall within normal values and do not vary.

11. BIOCHEMICAL STUDIES

11.1. INTRODUCTION

Biochemical indicators are used mainly to evaluate acute exposure to ionizing radiation [2]. Their use is limited by their broad individual variability.

Radiation produces a drop in concentration of nucleic acid in peripheral leucocytes in the blood [32, 33]. With this property, it is possible to estimate doses in the 0.1-8 Gy range when the normal nucleic acid levels of the individuals exposed are known and the analysis is performed between 24 and 72 hours after over-exposure [34-37]. For cases of chronic exposure, a proposal was put forward to classify the effect produced by radiations as low, moderate or severe, considering the decreased concentration of nucleic acids against the individual's normal value [32, 38]. On these premises, it was decided to determine whether a decrease in mean nucleic acid values had taken place in groups with different exposure doses and if, as the doses increased, there was an increase in cases showing nucleic acid levels below normal. Simultaneously, the influence of thyroid hyperplasia on the behaviour of nucleic acid levels was studied.

11.2. METHODOLOGY

Nucleic acid concentration was determined through the Krittskii and Alexandrov method [36], using blood drawn for conventional haematology tests. The method is based on the extraction of leucocytes from the blood through washing-up with a saponine solution, centrifugation, elimination of the rest of blood components by percloric acid 0.2 N in ice, centrifugation and rejection of what remains on the surface. The extraction of ADN and ARN was made using percloric acid 0.5 N through hydrolysis, followed by cooling and centrifugation. The concentration of nucleic acids was established by spectrophotometry, at 230 and 265 nm, using quartz pieces with 1 cm of light passage.

Some 445 children from 43 locations were selected and divided into 4 groups according to the ^{137}Cs surface contamination levels in their locations of origin, as shown in Table XLII.

TABLE XLII. CHARACTERISTICS OF THE GROUPS SELECTED FOR BIOCHEMICAL STUDIES

Group	Towns		Number of children			Age interval (years)
	Number	Surface Contamination [kBq/m^2]	Healthy	With hyperplasia	Total	
B1	20	0-37	82	83	165	6-14
B2	15	37-187	52	84	135	9-14
B3	7	>296	66	19	85	7-14
B4	1	unknown	--	--	60	9-12

The breakdown includes healthy children (selected from Group IV) and children with thyroid hyperplasia. The study of the influence of thyroid hyperplasia on the parameter's normal values was made among the subgroups of Group B1. Levels of 1.29-4.84 mg/100mL were chosen as the normal value interval in the subgroup of healthy children from Group B1.

11.3. RESULTS AND DISCUSSION

The mean nucleic acid values in healthy children and in children with thyroid hyperplasia from group B1 were 3.09 ± 0.90 mg/100 mL and 2.94 ± 0.89 mg/100 mL. The value intervals were 1.29-4.89 mg/100 mL and 1.16-4.72 mg/100 mL of total blood, respectively. The number of cases of thyroid hyperplasia surpassing the highest value interval was 6. No significant differences ($p > 0.05$) were found between both subgroups. Further analyses of Groups 2, 3 and 4 were performed jointly with both healthy and thyroid hyperplasia cases.

Other authors have reported that thyroid hyperplasia produces an increase in nucleic acid levels [39]. In this study, the absence of an increase in nucleic acid figures may be due to the fact that more than 90% of hyperplasia cases were in IA (71%), IB (22%) and only 6% and 1% of II and III, respectively.

The results obtained in the groups established are shown in Table XLIII. Contrary to expectations, the tendency observed is a slight increase in the mean value of nucleic acid as radioecological conditions change and the dose increases.

The four cases of low nucleic acid values are found in groups B1 and B2. The observed decrease was in all cases under 50%, whereby the damage was classed as slight [32].

TABLE XLIII. RESULTS OF NUCLEIC ACID DETERMINATION

Group	Mean ± S.D.	Interval	Percentage of cases with	
			low nucleic acid	high nucleic acid
B1	3.00 ± 0.90	1.20-4.80	0.6	3.6
B2	3.04 ± 0.94	1.16-4.92	2.2	3.6
B3	3.18 ± 0.95	1.28-5.08	0.0	5.8
B4	3.61 ± 1.37	0.87-6.35	0.0	1.6

11.4. CONCLUSIONS

No significant differences were found between the mean nucleic acid values of healthy children and those of children with thyroid hyperplasia.

Radioecological conditions and related doses did not influence the behaviour of mean nucleic acid values, contrary to expectations.

12. RISKS OF STOCHASTIC EFFECTS

12.1. INTRODUCTION

An increase in cancer frequency over spontaneous levels has been noted in groups of persons exposed to high doses of radiation. However, for low doses such as those received by children from areas affected by the Chernobyl accident, there is no conclusive epidemiological evidence of the induction of this stochastic effect. For this reason, even in large scale epidemiological research, it will be very difficult to detect the appearance of malignant tumours or other stochastic effects over and above spontaneous levels. Moreover, in the regions affected, the information available on stochastic effects is scarce.

Some authors believe that the risk analysis to estimate the consequences of radiation exposure can be applied only for regulatory purposes and not to quantify the possible effects produced by accidental exposures [40]. This complex issue is still being discussed. However, the present study examines certain issues concerning the adverse effects caused by the exposure to ionizing radiation of children from areas affected by the Chernobyl accident. These considerations have been included in this radiological and radiobiological study.

12.2. METHODOLOGY

The risk evaluation of stochastic effects was performed on 4506 children studied up until 1992.

As the population studied was composed of boys and girls under the age of 20 and the distribution was balanced (53% male and 47% female), the nominal probability coefficients for stochastic effects recommended by the ICRP were chosen for the entire population sample considered [41].

12.3. RESULTS AND DISCUSSION

In the results presented, the uncertainties raised by the initial information necessary for the thyroid and total dose estimation must be taken into account. They arise, first, because the bulk of the information comes from the children's individual questionnaires and focuses on the events they remember. Secondly, they reflect the scarcity of official information concerning surface contamination and the thyroid doses incurred by the local population.

When evaluating the adverse effects to health caused by the exposure to ionizing radiations, the conditions of exposure must not be overlooked. The evaluation by Cuban specialists [3, 13] and other authors [11] of the doses received by the inhabitants of these areas shows that the population were exposed to low doses and low dose rates, a factor which carries considerable weight in the selection of the nominal risk probability coefficients.

Table XLIV presents the entire group of children (4506) studied until 1992 in Cuba. As can be seen, for the cases studied, the commited mean doses over a 70-year projection are lower than those reported (80-160 mSv) by the ICHP [11], and much lower than the average dose produced over a lifetime by the mean natural radioactive background (160 mSv). Such low collective dose values make it practically impossible to quantify the adverse effect to health (0.05%) or to determine the fatal cancer ratio (0.03%) above spontaneous levels.

TABLE XLIV. DISTRIBUTION OF CHILDREN BY REPUBLICS STUDIED, UNTIL 1992

Republic	No. of children	Mean commited effective dose (mSv)	Collective commited effective dose (Sv.H)	Fatal cancers		Adverse effect to health	
				N	%	N	%
Belarus	367	12.3	4.5	0.2	0.06	0.3	0.09
Ukraine	3121	6.7	20.5	1.0	0.03	1.5	0.05
Russia	1018	4.6	4.7	0.2	0.02	0.3	0.03
Total	4506	6.6	29.7	1.5	0.03	2.2	0.05

Table XLV displays the evaluation of the adverse effect to health caused by thyroid irradiation in a group of 1535 Ukrainian children, and provides an estimate of the thyroid dose.

TABLE XLV. EVALUATION OF THE RISK OF APPEARANCE OF THYROID CANCER

Number of children	Mean dose equivalent:		Fatal cancers		Aggregate adverse effect to health	
	thyroid (Sv)	collective (Sv.H)	N	%	N	%
1535	0.18	282	0.22	0.02	0.42	0.03

Based on a spontaneous thyroid cancer incidence of 36 per million per year in this population, a figure comparable to that reported by other countries [46], it would be reasonable to expect a total of 2160 thyroid cancers per one million inhabitants within the next 60 years, of which 216 would prove fatal. This would represent 0.3 (0.02%) cases of spontaneous fatal thyroid cancers in the sample of 1535 cases studied. From an epidemiological point of view and bearing in mind the low spontaneous incidence and dose received, this particular group would be too small to study the increase in thyroid cancers due to radiation.

Once again, it must be underscored that the thyroid dose evaluation estimated in Cuba has a large degree of uncertainty, since it was derived from data on the contamination from ^{137}Cs of soil surface.

It must also be emphasized that the estimation of additional deaths from cancer in the different studies of the areas affected by the Chernobyl accident ranges from 0.05% to 1.05% [41]. This variation is primarily due to the different sources of reference, dose estimations and evaluations of the response to a given dose. Either way, it is necessary to bear in mind that the most pessimistic prognoses of additional deaths (1.05%) include a total of 100 000 deaths from cancer, while in the next 70 years the number of expected deaths from other causes reaches the figure of 9 500 000 in these regions [43].

12.4. CONCLUSIONS

- The aggregate adverse effect to health produced by the effective doses evaluated in the group of children studied in Cuba was estimated to be below 0.05%.

REFERENCES

[1] DOTRES, C., GARCÍA, O., Cuban Program for Medical Assistance to Children from Chernobyl, Rep. International Chernobyl Project, IAEA, Vienna (1991).

[2] UNITED NATIONS, Sources, Effects and Risk of Ionizing Radiation, (Report to the General Assembly with annexes) Scientific Committee on the Effects of Atomic Radiation, (UNSCEAR) United Nations publication sales No. E.88.IX.7, New York (1988).

[3] SUÁREZ, R.C., et al., ^{137}Cs Body Burden in a Group of Children Coming from Affected Areas Due to Chernobyl Accident, Nucleus **16** (1994) 10.

[4] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Report of the Task Group on Reference Man, Publication 23, Pergamon Press, Oxford and New York (1975).

[5] BRODSKY, A., Accuracy and Detection Limits for Bioassay Measurements in Radiation Protection, Statistical Considerations, Rep. NUREG-1156, Washington, DC (1986).

[6] SUOMELA, M., Whole Body Counters Studies in Radiation Protection and Clinical Research, STL-A45, Institute of Radiation Protection, Helsinki (1983).

[7] FRY, T.C., Probability and its Engineering Uses, D. Van Nostrand, New York (1928).

[8] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Limits for Intakes of Radionuclides by Workers, Publication 30, Pergamon Press, Oxford and New York (1980).

[9] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Age-dependent Doses to Members of the Public from Intake of Radionuclides, Part 2, Ingestion Dose Coefficients, Publication 67, Pergamon Press, Oxford and New York (1993).

[10] CRISTY, M., ECKERMAN, K.F., Specific Absorbed Fractions of Energy at Various Ages from Internal Photon Sources, Rep. ORNL/TM-8381/V1-7, Oak Ridge Nat. Lab., TN (1987).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, The International Chernobyl Project, Assessment of Radiological Consequences and Evaluation of Protective Measures, Rep. by an International Advisory Committee, the International Chernobyl Project, IAEA, Vienna (1991).

[12] USSR State Committee on the Utilization of Atomic Energy, The Accident of the Chernobyl Nuclear Power Plant and its Consequences, Parts I, II, Vienna (1986).

[13] SUÁREZ, R.C., et al., Dose Estimation from Different Pathways in a Group of Children Coming from Areas Affected by the Chernobyl Accident, Regional Congress on Radiological and Nuclear Safety, **II** 2nd part, Mexico (1993) 480.

[14] UNITED NATIONS, Ionizing Radiation: Sources and Biological Effects (Report to the General Assembly), Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), United Nations publication sales No. E.82.IX.8, New York (1982).

[15] STATE COMMITTEE ON HYDROMETEOROLOGY, Data on Radioactive Contamination in Settlements of the Ukrainian SSR by ^{137}Cs and ^{90}Sr, Moscow (1989).

[16] PANAMERICAN HEALTH ORGANIZATION, International Classification of Diseases, Vol 1, Scientific Pub. 353, PHO 9th Review, Mexico (1986).

[17] SMITH, C.H., Pediatric Hematology, Ed. Rev., Havana (1985).

[18] INTERNATIONAL ATOMIC ENERGY AGENCY, Medical Handling of Accidentally Exposed Individuals, Safety Series No. 88, IAEA, Vienna (1988).

[19] ROMANENKO, A.E., LEXTAREB, I.A.,Thyroid Dose and Endocrinological Monitory Organization in Ukrainian Inhabitants after the Chernobyl Accident, Med. Rad. **17** (1991) (in Russian).

[20] ILYN, L.A., PAVLOSKY, O.A., "Radiological Consequences of the Chernobyl Accident in the Soviet Union and Measures Taken to Mitigate their Impact", Nuclear Power and Safety, IAEA Bulletin **4,** IAEA (1987) 17.

[21] UNITED NATIONS, Sources and Effects of Ionizing Radiation (Report to the General Assembly), Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), United Nations publication sales No. E.94. IX.2, New York (1993).

[22] INTERNATIONAL ATOMIC ENERGY AGENCY, Biological Dosimetry, Chromosomal Aberration Analysis for Dose Assessment, Technical Reports Series No. 260, IAEA, Vienna (1986).

[23] INTERNATIONAL CONFERENCE ON HIGH LEVELS OF NATURAL RADIATION, Book of Abstracts, Ramsar, Islamic Republic of Iran (1990).

[24] GARCÍA, O., et al., Relationship Between “In Vitro” Gamma Radiation Dose and Chromosomal Aberrations in Human Lymphocytes, Nucleus **4** (1988) 20.

[25] GARCÍA, O., et al., Micronuclei Induction in Human Lymphocytes by Gamma Irradiation, Nucleus **12** (1992) 12.

[26] KONOPLYA, Y.A., International Chernobyl Project Rep., Vienna, Austria (1991).

[27] VOROBYON A., Chernobyl: Time Bomb Continues to Tick. Moscow News Weekly **33** (1991).

[28] STEPHAN, G., OESTREICHER, V., Mut. Res. 223 (1) 7-12 (1989).

[29] SALOMAA, S., RAHOLA, T., in 7th International Congress on Circumpolar Health, 8-12 Jun. Ruotsi, Finland (1987).

[30] LUBIN, E., personal communication (1991).

[31] SHEVCHENKO, V.A., et al., in "All Union Radiobiological Conference" M.INIS-SU-210. **3** (1989) 657-658.

[32] PUCHOVA, S.M., "Characterization of Radiation Damage Using Blood Nucleic Acid Contents", in Current Problems in Radiation Medicine and Radiobiology, Moscow (1975) 91.

[33] TENCHOVA, B., PANTEV, T., "Early Diagnostics of Radiation Damage Through the Nucleic Acid Concentration in Blood", Roentgenology and Radiology **1** (1981) 53-57.

[34] MINKOVA, M., PANTEV, T., TENCHOVA, B., Time Course of Changes in Leucocyte Nucleic Acids in Rats Exposed to a Wide Range of Radiation Doses, personal communication (1987).

[35] TENCHOVA, B., PANTEV, T., MINKOVA, M., Temporal and Dose Characteristics of Nucleic Acids Reduction in the Leucocytes of Irradiated Mice", Stralentherapie **159** (4) (1983) 248-50.

[36] KRITSKII, G.A., ALEXANDROV, S.V., "Diagnosis of Radiation Injury to the Body Using Determinations of Blood Nucleic Acids", Doklady Academmil Naud SSSR, Vol II (1982) 44-48.

[37] MINKOVA, M., PANTEV, T., NICHOV, N., "Alpha Particles Induced Damage Assessed by Blood Nucleic Acids Levels", In Problems of Roentgenology and Radiobiology, Medical Academy Center for Scientific Information in Medicine and Public Health **VII** (1986) 30.

[38] MINKOVA, M., PANTEV, T., "Prognostic Possibilities in Leucocyte Nucleic Acid Levels for Appraising Radiation Damage to Rats", Medical Academy Institute of Roentgenology and Radiobiology, Sofia (1976).

[39] LOEB, C., Treatise of Internal Medicine, Ed. Rev., Havana (1989).

[40] ILYIN, L.A., et. al., Radiocontamination Patterns and Possible Health Consequences of the Accident at the Chernobyl Nuclear Power Station, J. Radiological Protection **10** (1) (1990).

[41] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, 1990 Recommendations of the International Commission on Radiological Protection, Publication 60, Pergamon Press, Oxford and New York (1991).

[42] GETNER, N.E., Thyroid Cancer in Children from Belarus, CANDU Owners Group, **3** No. 2 (1994).

[43] ADELSTEIN J., Uncertainty and Relative Risks of Radiation Exposure, JAMA, **258** (5) (1987) 655-70.

Appendix

PSYCHOLOGICAL STUDY OF THE CHILDREN FROM AREAS AFFECTED BY THE NUCLEAR ACCIDENT IN CHERNOBYL WHO WERE TREATED IN CUBA

L. BECQUER, P. PUIG, A. LORENZO, M. VASILEVA
Tarará Paediatric Hospital

R. PÉREZ, B. PÉREZ
Havana Higher Institute of Medical Sciences

G. AMARGÓS
Havana Psychiatric Hospital

SUMMARY

This appendix contains the findings of the psychological studies carried out on children from areas affected by the Chernobyl accident who were inpatients at the Tarará Paediatric Hospital in Cuba. Variables such as anxiety, depression, post-traumatic stress, material and psycho-social losses were analyzed, together with some aspects relating to the psychological preparedness they had before the disaster and others on their degree of satisfaction with the specialized medical treatment they received in Cuba.

A number of psycho-social reactive disorders related with the Chernobyl accident were detected in these children, together with a consistent improvement in their state of mental health; some specificities were also observed in chronically ill patients due to the impact of psycho-social factors. Finally, a set of hypotheses to be corroborated in future research projects was developed and is outlined in the latter portion of this appendix.

INTRODUCTION

Starting in the spring of 1990, some fifteen thousand children received medical treatment in Cuba along with their relatives and/or accompanying adults. All of the children were from the areas affected by the nuclear accident in Chernobyl. They were offered specialized medical and comprehensive care. The Cuban programme of family physicians performed clinical, biochemical and psycho-social studies on this group of children. Psycho-social issues were examined in the knowledge that to ignore them in the aftermath of the accident would have been wrong, as analyses of other similar disasters have demonstrated [1-3].

In recent years this set of problems has been dealt with as a priority in health psychology, in a discipline known as victimology. Experiences from around the world appear in the significant WHO and PAHO literature on this subject. According to these sources, the extent of psycho-social damage is related to the impact of the disaster (duration, intensity and characteristics), to variables in the pre-impact and post-impact personality of the victims and to other factors arising from the changes in lifestyle and living standards of the affected population [4-6].

The medical and psychological team believes that the conclusions of the Advisory Committee of the Chernobyl International Project [7] are of great interest. The Advisory Committee studied the consequences of the accident in the light of the relative importance of the damages caused by the — at times overestimated — ionizing radiations. However, the Chernobyl International Project did not sufficiently address damages of a psycho-social character.

Psychology acknowledges that the psyche in all its manifestations is an active product of the interaction of the individual with his or her environment. But the role of the individual is still the subject of controversy. Therefore, approaching the problems of adolescents, particularly their possibilities of readapting to unpleasant or difficult conditions in nature or their social environment, is of particular interest to social scientists. The accident at the Chernobyl nuclear power station is a case in point.

Using this theoretical concept as a starting point, the Psychology Department of the Tarará Paediatric Hospital undertook several studies of this population together with other institutions and under the auspices of the Ministry of Public Health, National Division of Psychology. The present appendix is a comprehensive review of the research topics studied by the team of medical experts and psychology specialists.

GENERAL PURPOSE

To evaluate the system of psychological actions which the children under observation in Tarará experienced, both as to the variables of the disaster itself and as to variables of individual characteristics having a bearing on their psycho-social adaptation.

SPECIFIC OBJECTIVES

1. To assess the improvement in the mental health of the children during their stay in Cuba, as well as their satisfaction with the various services received.

2. To specify certain characteristics of the diseases in children with chronic disorders.

3. To identify and quantify the main factors, directly related to the disaster and the victims' perceptions, which influence the psycho-social adaptation of the population.

4. Based on the research findings, to design a system of psychological actions with a view to facilitating the children's psycho-social adaptation.

SAMPLE AND METHODOLOGY

The team of specialists assembled a random sample of 404 adolescents from the areas affected by the nuclear accident in Chernobyl. The subjects were boys and girls between 11 and 17 years of age. The team selected this age interval because of the time elapsed since the occurrence of the accident (1986), and because it wanted to evaluate these adolescents in the period 1990-1994. This selection criterion meant that all of them were at least six years old at the time of the accident. But as they had grown intellectually in the meantime, they could offer their own views as to their environment.

The sample was divided into two groups: the first, composed of 140 persons (34.65%), included patients with chronic diseases (102 children with vitiligo, 26 with alopecia and 12 with psoriasis) who travelled to Cuba to receive specialized medical care, and the second, of 264 individuals (65.35%) considered healthy, who travelled to Cuba for a general medical check-up and to rest in a sanatorium environment. Healthy adolescents were considered to be a control group in relation to the chronically ill. The adolescents remained in Cuba for approximately 45 days.

The age distribution of the sample is given in Table I.

TABLE I. DISTRIBUTION OF THE SAMPLE (FIGURES IN PER CENT)

	Ages (Years)				
Groups	11-12	13-14	15-16	17-18	TOTAL
I - Chronically ill	17.15	65.71	16.43	0.71	34.65
II - Healthy	17.05	71.97	10.61	0.37	65.35
Total Population	17.08	69.80	12.62	0.50	100.00

The distribution by sex of Group I was 64.29% females and 35.11% males and Group II, 58.85% females and 41.15% males. In the total sample under study, 61.5% were females and 38.5% were males.

The general data of this population were stored in the database of the Quest Tree Automated system for clinical observation. In addition, the following tests and questionnaires were used:

1. Questionnaire concerning satisfaction with services rendered. They were completed at the end of the children's stay in Cuba. (Variable: satisfaction with services.)

2. State-trait Anxiety Inventory for Children. STAIC test by C. D. Spielberger. Completed at the beginning and the end of the children's their stay in Cuba. (Variable: anxiety.)

3. Questionnaire on depression based on state-trait depression inventory (IDERE) by J. Grau and M. Martin, for this research project. Completed at the beginning and the end of the children's stay in Cuba. (Variable: depression.)

4. Dembo Rubinstein Self-evaluation Scales (modified by T.M. Gabrival). These measure a subject's self-evaluation level as to health, intelligence, character and happiness. (Variable: self-evaluation.)

5. Eyzenck's Personality Inventory (modified by the Psycho-diagnosis Institute of Kiev, Ukraine). It measures the prevalence of introversion, extraversion, and neurotism in developing individuals. (Variable: personality.)

6. Thomas Test measuring the typical reactions in conflict situations. (Variable: conflict confrontation.)

7. Questionnaire on the magnitude of losses, including the following variables:

    a) Material losses
    b) Relationship losses
    c) Subjective well-being losses

8. Credibility scale on the extent of losses. This measures the degree to which the individual saw the extent of his losses at various times after the disaster. (Variable: credibility.)

9. Questionnaire on individual evaluation of the information received on the disaster (Variable: degree of information.)

10. Questionnaire on vital events measuring the occurrence of traumatic events before the disaster. (Variable: vital events.)

11. Questionnaire on destiny control. This measures the possible interferences of the disaster in the future life of the children from the areas affected by the nuclear accident in Chernobyl. (Variable: destiny control.)

All the information obtained was stored in a database for further statistical analysis.

Comparative and correlative analyses were made with the aid of the Stadraf software, version 4.1, 1992, using an $\alpha = 0.05$ coefficient and its K coefficient for the comparison of identical parameters of two population samples. The statistical significances provided always take account of two groups, the healthy and the chronically ill.

FINDINGS AND DISCUSSION

The children considered their stay in Cuba to be very satisfactory.

As shown in Table II ($\alpha = 0.05$, K = 1.45 E-17), almost 92% of the children valued their stay in Cuba as good or very good, with a trend towards a more marked satisfaction in children with chronic diseases. In spite of a new cultural context and difference in living conditions, the children adapted well to our environment.

TABLE II. EVALUATION OF STAY IN CUBA (FIGURES IN PER CENT)

Variables	Chronically Ill	Healthy	Total population
Very good	72.14	65.91	69.07
Good	21.43	25.00	23.76
Fair or bad	6.43	9.09	8.17

$\alpha = 0.05$ K = 1.45 E-17

The findings of the anxiety evaluation point in the same direction.

As can be seen in Table III (initial $\alpha = 0.05$ K = 7.33 E-15; final $\alpha = 0.05$, K = 2.10 E-4), anxiety as a transient emotional state upon arrival in Cuba has an average value of $x = 44.18$. It tends to be higher ($x = 50.27$) in the chronically ill, which is statistically significant. At the end of their stay in Cuba the children's anxiety state tends to decrease, a trend more marked in the chronically ill.

When analyzing these values of anxiety, it can be seen that most of them tend to be mean or high, and very few are low. These values show consistencies with similar studies undertaken in the Chernobyl child population [8, 9]. This can mean that the very fact of coming to a colony far away from their usual place of residence, without adequate preparation, was a strong stress factor for the adolescents. At the end of their stay however, a decrease in stress factors was observed owing to reasons further explained below.

TABLE III. STAIC TEST: ANXIETY STATE (X)

Data	Chronically ill	Healthy	Total population
(1) Initial	50.27	40.95	44.18
(2) Final	43.19	39.57	40.82

(1) $\alpha = 0.05$ K = 7.33 E-15

(2) $\alpha = 0.05$ K = 2.10 E-4

Chinkina [10] has recently presented a correlation between the verified radioactive exposure in the Chernobyl Nuclear Accident and the evolution of negative psychic conditions and psycho-physical disorders. He found high levels of reactive anxiety and post-traumatic stress, whatever the level of exposure. In other words, for this population, the Chernobyl disaster implies potential anxiety manifestations such as those highlighted in the studies of other populations affected by disasters: Hiroshima [1, 2], Three-Mile Island in the U.S.A. [3], the Nevado del Ruiz volcano disaster in Colombia [6], the radiological accidents of Goiânia [12-14] in Brazil and El Salvador [15]. As outlined in Table IV (initial $\alpha = 0.05$, K = 8.77 E-14; final $\alpha = 0.05$, K = 1.79 E-8), anxiety as a trait is concentrated in the mean values (x = 40.04 initially and x = 38.57 finally).

TABLE IV. STAIC TEST: ANXIETY TRAIT (X)

x Data	Chronically ill	Healthy	Total population
(1) Initial	44.04	37.93	40.04
(2) Final	41.46	32.02	38.57

(1) $\alpha = 0.05$ K = 8.77 E-14

(2) $\alpha = 0.05$ K = 1.79 E-8

The chronically ill tend to display a concentration over the mean values (see Table IV). Comparing these results with similar studies carried out with the aid of STAIC tests on adolescent victims offers interesting findings. For example, Drinevski et al. [9] obtain a 44.02 average anxiety trait, which is higher than that of our healthy group, but similar to that of the chronically ill group. The results obtained characterize this population as showing significant anxiety values, both in terms of the relatively stable trait and the transient emotional state that tended to decrease, while never reaching low values, during their stay in Cuba.

Another emotional state of great incidence in the psychological studies of disasters is depression.

As displayed in Table V (initial $\alpha = 0.05$, K = 5.59 E-6; final $\alpha = 0.05$, K = 0.14), depression as an emotional transient state tends to decrease from one evaluation to the next, indicating an improvement in the state of mind of these children towards the end of their stay in Cuba. However, the score concentrations never reach low levels according to the questionnaire, although in the case of the chronically ill, the improvement of their depressive state is more marked.

TABLE V. DEPRESSION QUESTIONNAIRE: DEPRESSIVE STATE (X)

x Data	Chronically ill	Healthy	Total population
(1) Initial	52.48	48.13	49.63
(2) Final	44.61	46.09	45.57

(1) $\alpha = 0.05$ K = 5.59 E-6
(2) $\alpha = 0.05$ K = 0.14

As to depression as a trait, Table VI (initial $\alpha = 0.05$, K = 0.64; final $\alpha = 0.05$, K = 0.48) shows a population with relatively stable depression traits, judging by the significant values recorded. There are no statistical differences between the healthy and chronically ill groups. Despite the unavailability of data from similar control groups, these values are consistent with those obtained from the projection test made by the International Advisory Committee of the International Chernobyl Project [7], and those of record for Hiroshima survivors [1, 2], the inhabitants of Three Mile Island (USA) [3, 11], the victims of the radiological accidents of Goiânia in Brazil [12-14] and El Salvador [15], and the victims of the Nevado del Ruiz volcano eruption in Colombia [6]. In essence, depression seems to be a constant psychological trait in the post-impact period of a disaster.

TABLE VI. DEPRESSION QUESTIONNAIRE: DEPRESSION TRAIT (X)

x Data	Chronically ill	Healthy	Total population
(1) Initial	42.41	42.90	42.73
(2) Final	39.55	40.29	40.03

(1) $\alpha = 0.05$ K = 0.64
(2) $\alpha = 0.05$ K = 0.48

Turning to personality variables in Table VII ($\alpha = 0.05$, K = 1.57 E-10), self-evaluation in general shows a differential character which indicates certain inadequacies. While the dominant trend in the chronically ill is to underevaluate themselves (as to health, happiness and intelligence, for example), this inclination might be linked to defense mechanisms, reinforcing factors and/or associated secondary gains.

Comparing these results with studies carried out by the team at the Institute of Psychology of the Ukranian Academy of Sciences shows coincidences and discrepancies. Chernichev et al. [16] detect a trend towards over-evaluation. Nonetheless, they consider their average values to be typical of adequate self-evaluation, even though their results differ from ours.

TABLE VII. DEPRESSION QUESTIONNAIRE: DEPRESSION TRAIT (X)
(FIGURES IN PER CENT)

Global evaluation	Chronically ill	Healthy	Total population
Over-evaluation	2.86	15.15	10.89
Adequate	45.00	52.27	49.75
Under-evaluation	52.14	32.58	39.35

$\alpha = 0.05$ K = 1.57 E-10

The team believes that the important role played by self-evaluation is reflected in the developing personality self-regulation of adolescents. Apparently, as observed by Cuban researcher F.L. González Rey [17], some of the sources of stress, depression, anxiety and frustration arise from individual self-evaluation and the assessment of future prospects. Inadequacies which affect individual self-evaluation produce very strong negative feelings. In this regard, if self-regulation problems become chronic (as is generally the case for disaster victims, due to negative psycho-social influences from the family, school, oral and extra-oral communication, environmental characteristics, etc. [4, 5, 7, 11, 12, 16]), it can be assumed that similarly strong feelings will be generated by the negative emotional reactions associated with them.

Likewise, the emergence of strong negative emotions (anxiety, depression) with inadequacies in self-evaluation is reflected in certain conditions of personality development. As evidenced in Table VIII ($\alpha = 0.05$, K = 4.94 E-12), neurosis prevails in the personality traits detected in the total population under study (45.79%), followed by introversion (32.18%) and extroversion (22.03%). This trend is most marked in the chronically ill (neurotic state: 57,14%; introversion: 28.57% and extroversion: 14.29%, respectively).

When comparing these results with similar studies conducted on children victims of Chernobyl, differences and coincidences are found. The team does not agree with the results obtained by Ribalka [8] as to the prevalence of introversion over neurosis as a trait.

However, the team agrees with the majority trend of neurotic traits (53%) presented in the studies carried out by Drinevsky et al. [9]. But, in essence, the combinations of these data may suggest alarm at the occurrence of neurotization, possibly associated with the various social and psychological inadaptation mechanisms and corresponding maladjustments, both current and prospective, which must be taken into account in this victim population, an element already pointed out by other authors [7-9, 16, 18].

TABLE VIII. EYZENCK'S PERSONALITY INVENTORY (FIGURES IN PER CENT)

Variables	Chronically ill	Healthy	Total population
Neurotism	57.14	39.77	45.79
Extroversion	14.29	26.14	22.03
Introversion	28.57	34.09	32.18

$\alpha = 0.05$ K = 4.94 E-12 ()

An analysis of individual control mechanisms, which will address confrontation styles in conflict situations, will complement these findings.

According to the data in Table IX ($\alpha = 0.05$, K = 3.62 E-5) and Table X ($\alpha = 0.05$, K = 1.94 E-3), the total population sample shows the highest conflict confrontation style values grouped in reactions which characterize typically inadequate coping (compromise, evasion, adaptation). This the team associates with the statement by the Advisory Committee of the International Chernobyl Project [7] in relation with the prevalence of coping styles leading to chronic apathy. The chronically ill show a statistically significant prevalence of inadequate coping styles.

Even when the stay in Cuba was short — 45 days on average — significant changes could be distinguished between the initial and the final assessment as to the structure of confrontation styles. At the end of the stay in Cuba a slight increase in the concentration of mean values on more adequate confrontation styles (competence, co-operation) could be detected, implying more direct and less evasive coping in various problematic situations. Here again, the chronically ill obtain statistically significant values which are higher than the ones registered for healthy adolescents.

TABLE IX. STYLES OF CONFLICT CONFRONTATION: THE THOMAS TEST (INITIAL RESULTS)

Styles	Chronically ill	Healthy	Total population
Competence	3.0	7.0	4.90
Co-operation	4.2	6.0	5.25
Compromise	8.2	5.8	7.35
Evasion	8.6	6.6	7.25
Adaption	6.0	4.6	7.25

$\alpha = 0.05$ K = 3.62 E-5

The mean values (x) of style occurrence were taken in the Thomas test, based on the answers possible.

TABLE X. STYLES OF CONFLICT CONFRONTATION: THE THOMAS TEST (FINAL RESULTS)

Styles	Chronically ill	Healthy	Total population
Competence	6.45	7.86	5.08
Co-operation	6.96	7.04	6.99
Compromise	7.06	6.10	6.87
Evasion	6.09	5.00	5.32
Adaption	5.44	4.00	5.74

$\alpha = 0.05$ K = 1.94 E-3

When considering these conflict situations as potentially stressful factors, the team agrees with Nikulenko, et. al. [19] in confirming that stress in any situation is inversely proportional to an individual's capacity to respond in an effective manner, while it is also directly dependent on how significant the consequences of these situations are to him or her. Apparently, the satisfactory evaluation by this population of its stay in Cuba and the drop in anxiety and depression values registered during such stay, inter alia, indirectly impact on the structural and dynamical reorganization of its coping styles.

Another tool available for the characterization of psychological impact in disaster studies is post-traumatic stress. In this particular case, the preparedness of the population before the disaster must first be taken into account. This variable was assessed with the aid of the Disaster Credibility Scale.

As can be gathered from Table XI ($\alpha = 0.05$, K = 1.64 E-1), an important percentage of the persons under study (50.25%) did not believe immediately that reports about what had happened were true, while another important part (45.30%) believed the reports immediately; a minority (4.45%) did not believe them at all. The trends are the same in the chronically ill and in the healthy population, except for the statistically significant increase observed in the healthy group which did not believe the disaster had occurred (Table XI). This situation is described in other studies including populations hit by a disaster without the aftermath of chronic diseases. It is understood as a kind of defense mechanism, a phase of development of psycho-social reactions [4-7, 11, 12, 14].

Being well informed of the circumstances of a disaster after it has occurred contributes to the psychological balance of the victim population [4, 5, 7]. Let us consider the results of the Scale of Information Adjustment in Table XII below ($\alpha = 0.05$, K = 2.35 E-4).

TABLE XI. DISASTER CREDIBILITY (FIGURES IN PER CENT)

Variables	Chronically ill	Healthy	Total population
Immediate	47.14	51.89	50.25
Mediate	45.71	45.07	45.30
None	7.14	3.03	4.45

$\alpha = 0.05$ K = 1.64 E-1

TABLE XII. INFORMATION ADJUSTMENT (FIGURES IN PER CENT)

Variables	Chronically ill	Healthy	Total population
Very insufficient	40.25	32.95	35.40
Insufficient	32.14	39.77	37.13
Sufficient	27.85	27.27	27.47

$\alpha = 0.05$ K = 2.35 E-4

It follows from these results that more than half of all the individuals surveyed considered that the information they received was insufficient to very insufficient. This trend was more significant statistically for chronically ill patients (Table XII). Difficulty with information became another generator of negative emotions, either anxiety or depression, since ignorance and mistaken or exaggerated reports have a negative impact on the mental health of populations hit by a disaster, as several specialized studies made prior to the Chernobyl accident have shown [1, 3-7, 11-13].

For example, according to the findings of the team of Polish researchers under the supervision of A. Bieli [20], the so-called 'ecological' information plays an imprtant role in causing stress during ecological crises. Under its influence, a set of defense mechanisms such as the refusal to receive information, the denial of the information received and even aggressiveness occur.

The specialized literature refers to the general assessment of losses in any disaster as one of the main indicators of psychological impact.

The results of Table XIII ($\alpha = 0.05$, K = 6.55 E-9) indicate that more than half of the population interviewed considered that it suffered significant losses. Again, this trend is significantly higher for the chronically ill.

TABLE XIII. GLOBAL LOSSES (FIGURES IN PER CENT)

Variables	Chronically ill	Healthy	Total population
Few	13.57	20.08	17.82
Substantial	62.45	45.07	50.99
Very big	24.29	34.85	31.19

$\alpha = 0.05$ K = 6.55 E-9

Table XIV highlights the losses in the system of social relations ($\alpha = 0.05$, K = 9.104 E-14). The noteworthy feature of this table is the similarity between the values given by healthy adolescents as to "few" and "substantial" social relations losses (46.96% and 50.00%, respectively), while for the chronically ill, the percentages of "substantial" and "very large" relations losses are considerably higher (62.45% and 24.28%, respectively). Significantly, in the total population, the losses categorized as "very large" received a low rating (10.39%). Moreover, the references to the losses in the system of negative relations generated in the family, the school, the peer group and their respective communities were mentioned by the interviewees themselves. These findings are consistent with those of other studies of the populations from the areas affected by the nuclear accident in Chernobyl [7,10,16] and analyses of other disasters [1-6, 11-15].

In a nuclear disaster situation, labelling is possibly one of the most damaging psychological behaviours.

As follows from Table XV ($\alpha = 0.05$, K = 12.125 E-10), approximately 65% of the persons surveyed perceived some degree of labelling. Compared with with the healthy adolescents, the chronically ill perceived an increase in the degree of labelling of up to 98%, which is statistically very significant. In other words, feeling different in some negative aspect, being a victim but also a chronic patient, produces more emotional discomfort, since chronically ill patients perceive a negative stigma because the medical treatment they receive is different [21]. Additionally, according to studies undertaken by the authors [22], most of the chronic patients tend to associate the explanations of their disease as well as its evolution and complications with these stigma and with assessments of the disaster as such.

Furthermore, radioactivity is regarded as a kind of initial and sustained germ causing diverse problems in populations from areas affected by radiation disasters [2, 7-9, 11, 12, 15, 20, 22, 23].

TABLE XIV. LOSSES IN THE SYSTEM OF SOCIAL RELATIONS (FIGURES IN PER CENT)

Variables	Chronically ill	Healthy	Total population
Few	13.57	46.96	35.40
Substantial	62.45	50.00	54.21
Very large	24.29	3.03	10.39

$\alpha = 0.05$ K = 9.104 E-14

TABLE XV. PERCEIVED LEVEL OF LABELLING (FIGURES IN PER CENT)

Variables	Chronically ill	Healthy	Total population
Little	2.14	45.83	30.69
Average	67.39	40.16	45.51
Large	30.71	14.01	19.80

$\alpha = 0.05$ K = 12.125 E-10

Table XVI (α = 0.05, K = 10.735 E-8) shows 62.18% of the total population interviewed evaluated the level of radioactivity they received in their country (Ukraine) from average to large. This topic shows statistically significant differences between the healthy and the chronically ill. In the latter group, some 75.54% of the interviewees evaluated radioactivity as average to large.

These results are in agreement with the findings of the Advisory Committee of the International Chernobyl Project [7] and other studies on radioactivity related disasters [1, 3, 8, 9, 11-15, 23, 25]. In the cases where radioactivity and the doses are overestimated by specialized agencies, their actual effects are also overestimated and are considered to be the cause of a great number of health-related problems. These results are confirmed by the findings of a six-month longitudinal study carried out on a group of chronically ill patients during their stay in Cuba [22].

TABLE XVI. SUBJECTIVE EVALUATION OF RADIOACTIVITY IN CURRENT PLACE OF RESIDENCE – UKRAINE

Variables	Chronically ill	Healthy	Total population
Little	24.46	44.70	37.62
Average	26.69	48.86	41.09
Large	48.85	6.44	21.29

$\alpha = 0.05$ K = 10.735 E-8

To conduct a thorough study of post-traumatic stress, it is imperative to record the significant events experienced by the affected populations prior to the occurrence of a disaster.

According to Table XVII (α = 0.05, K = 11.143 E-7), nearly 47% of the total population interviewed reported stress generating situations prior to the disaster. As in previous evaluations, the values of the chronically-ill patients showed very significant statistical differences in this area. This finding concurs fully with the specialized studies mentioned in our comments. In addition, it coincides with the observations made by the adolescents interviewed, their families and other accompanying adults, as they characterized their life after the accident as a traumatic period full of vital events.

The knowledge and accuracy of these stress related vital events before the disaster should be considered and included in the assessment of the dynamic nature of human adaptation to extreme situations [19].

Moving ahead, let us turn to terminal values, namely, the main objectives of evolving individuals reflecting on their long term prospects.

TABLE XVII. STRESS IN VITAL EVENTS BEFORE THE DISASTER (FIGURES IN PER CENT)

Variables	Chronically ill	Healthy	Total population
None	15.00	72.72	52.72
One	22.14	16.67	18.56
More than two	62.86	10.61	28.72

$\alpha = 0.05$ K = 11.143 E-7

As is well known, during adolescence, self-definition forges images and ideas about future adulthood, and ideals take shape. In this respect, adolescents from the areas affected by the Chernobyl accident are in a very special position, since they must introduce changes in future vital values [24-27] such as future control of their destiny.

As can be seen in Table XVIII (α = 0.05, K = 6.49 E-4), 68.57% of the adolescents surveyed imagine their control over their future destiny as victims as insufficient to very insufficient. When comparing the chronically ill with the healthy adolescents, the chronically ill demonstrate a higher and statistically significant trend towards higher insufficiencies in relation to control over their destiny.

TABLE XVIII. FUTURE DESTINY CONTROL (FIGURES IN PER CENT)

Variables	Chronically ill	Healthy	Total population
Very insufficient	49.67	21.97	31.43
Insufficient	32.14	39.77	37.14
Sufficient	18.57	32.26	31.43

$\alpha = 0.05$ K = 6.49 E-4

In general, this population evaluates its insufficiencies in relation to the future against the backdrop of the multiple psycho-social consequences associated with the Chernobyl disaster, where the fact of continuing to live in polluted areas creates a permanent source of tension and insecurity. Because of the potential impact of ionizing radiation, children are overly concerned about their own lives and health, that of their relatives and even their future children [7, 10, 22, 24-27].

Another comparatively important latent problem is the evaluation made by the children studied of the multiple evacuations they underwent. They expressed negative opinions about the influence of evacuation on their psycho-physiological condition, their learning abilities and even the moral and social behaviour of individuals in general. In similar studies, significant differences have been noted between evacuated and non-evacuated adolescents, along with the problem of an excessive attention to displaced individuals, which exacerbates negative stigma. Evacuated families increase the number of prohibitions on their children, constantly express the possible negative effects of the disaster in their oral and extra-oral communication and devote less time and attention to their children's education [7, 10, 22, 24-27].

On to an in depth analysis of the instances of self-reflection and emotional reactions within the set of variables studied.

Based on its findings, the team evaluated the psycho-social alterations detected bearing in mind that emotions are bodily reactions which play an important role in health. This relationship has been demonstrated in numerous experimental studies showing how an emotional stimulus can produce pathological changes in the body [28]. This is not a simple stimulus/emotion-response/disease relationship. Personal experiences and attitudes towards reality are essential aspects in this definition of emotion. Thus, according to J. Reykouski et al. [29], chronic emotional reactions may lead to chronic pathologies which emerge in personalities with a given strategy to confront life.

This seems to be the case of the substantial differences found in the chronically ill patients where negative emotional reactions (including the psycho-social consequences of the disaster as such) are closely linked to the aetiopathogenesis, course, evolution and specialized treatment provided. Nearly 90% of the subjects fell ill after 1986 and strongly believed that their chronic illness was a result of the Chernobyl disaster and its aftermath. In a study undertaken using projection techniques (test of colour association and free and guided drawings) with a group of chronically ill adolescents (vitiligo, alopecia and psoriasis), the team found that in 85% of the cases, evaluations related to the Chernobyl disaster, evacuations, and losses in the system of social and psychological support characterized inter alia the causes that generated their disease, made it worse or caused new complications [30]. In a study then conducted by using a questionnaire drafted specifically for this purpose [31], the team found a similar trend, whereby the adolescents associated their chronic disease with the possible consequences of the Chernobyl accident: 94% of the subjects considered the accident to be the stress which brought on the disease. Hence, the alterations detected in the internal (subjective) condition of the disease are caused by the accident. Nonetheless, the health of the chronically ill adolescents improved more markedly during their stay in Cuba than that of the healthy group, a result possibly associated with the effectiveness of the specialized medical treatment they received.

In agreement with specialized research in the area of technological disasters (to which Chernobyl belongs), the team felt that adolescents to a large extent tend to be affected by acute and chronic stress [32] as a consequence of these disasters, characterized by psychological symptoms (anxiety, depression). These symptoms tend not only to compound the experience of the various negative emotional states but to fix waiting states of the possible negative effects, affecting above all the subjective mechanisms of the psychic activity of children.

The set of reactive changes to the disaster detected in this study may be categorized as post-traumatic stress syndrome.

This syndrome causes a breach in the logical consistency between the objectives and the means to their solution, because of the existing gap between the possibilities and solution experiences to problems of such magnitude and novelty.

These findings allow to formulate a number of hypotheses to be verified in subsequent research efforts. It seems that the psychological impact expressed as anxiety and depression was substantial. Although these symptoms tended to abate while the adolescents remained in Cuba, the levels recorded are dramatic for this age group.

The psychological preparation of the population seems to have been insufficient and the information it received about the disaster was not convincing. Most of the individuals surveyed believed they suffered important material and social losses together with labelling, stressful vital events and insufficiencies in the control of their future.

Additional to all of the above are the characteristics of an evolving personality, inadequate self-evaluation, and neurotic trends and insufficient coping styles in the confrontation of stressful situations.

Such factors led to many changes, including, inter alia, a decrease in working capacity (learning capacity), and high fatigue [7, 16, 24, 33, 34]. Undoubtedly, this reflected on the adaptability of the children to the most diverse conditions of daily life. However, the trip to Cuba did not generate significant expressions of inadaptation, and the adolescents considered their stay to have been satisfactory, since they made new friends, experienced new living conditions, received specialized medical care, and encountered adequate concern for their health. These findings are consistent with previous studies by the authors [35].

According to Abreu Vasconcelos L. [36], with whom the team concurs, the system of psychological actions offered in Cuba to this population, together with the specialized actions taken in sanatorium surroundings based on the Cuban experience with family medical care, was considered by the children under observation to be satisfactory and beneficial to their physical and mental health.

Finally, the development of nuclear energy is necessary for scientific and technical progress because of the shortage of fossil fuels. Apart from the fact that any seismic movement of great intensity may damage nuclear engineering works, just as any technical difficulty or subjective negligence, no technological systems are infallible. Therefore, there is a need to improve systems of radiological emergency with a psychological profile [13, 23, 36, 37]. As consistently stated by Dr. Hiroshi Nakajima, General Director of the World Health Organization (WHO): "Catastrophes do not warn. Let us be prepared" [38].

CONCLUSIONS

1. The individuals surveyed evaluated as positive their stay in Cuba, underlining satisfaction with the specialized medical services received.

2. Significant values of anxiety and depression were detected in the sample population, with a tendency to decrease at the end of the stay in Cuba, although never reaching low levels.

3. Alterations were found in evolving personalities, with a prevalence of neurotic features, inadequate self-evaluation, and coping failures, among others.

4. Most believe to have suffered significant losses, above all in their social relations system.

5. The children studied perceived a significant degree of labelling and stigmatization because of the disaster.

6. They tended to over-value the real effects of radioactive pollution on human life, up to the point of believing radioactive pollution causes diseases.

7. The psychological preparation of the population prior to the accident and the information received about the disaster seem to have been insufficient.

8. In each case, the condition of a disease as perceived by a subject presented inadequacies as to reality, owing to the substantial influence of the cognitive evaluations and psychosomatizations.

9. The chronically ill expressed a higher number of negative opinions on the disaster. Their improvement during their stay in Cuba was also more pronounced.

10. The social situation of this population, characterized by a set of stressful situations, has an impact on the personality development of the children.

11. In general, because of its repercussions, the Chernobyl disaster is considered to be an extreme, novel and complex situation.

12. Finally, the signs of improvement in the health of the children during their stay in Cuba (particularly their mental health) leads the team to believe that a system of specialized psychological and medical actions contributes to the psycho-social readaptation of a population that has been affected by a disaster.

RECOMMENDATIONS

1. In order to decrease the negative consequences of information failures, to maintain victims informed, thoroughly and clearly, about the most diverse physical, medical, meteorological, and radiological aspects of a disaster, using different direct or indirect media.

2. To promote multidisciplinary and multi-factorial studies of the population.

3. To offer specialized psychological aid, identify the specificity of the social and psychological situation of the victims and find more adequate ways to train for strategies to cope with disasters.

4. To design programmes of psychological preparedness actions for populations which can potentially be the victims of any type of disaster.

5. To search for various ways to exchange information and research findings on psychology applied to disasters with specialized institutions around the world.

REFERENCES TO THE APPENDIX

[1] KUBO, Y., "Study of Human Behaviour Immediately After the Atomic Bombing of Hiroshima", Socio-psychological Study Pertaining to the Atomic Bomb and Atomic Energy, In. Shinrigaku Kenkyu, Japanese Journal of Psychology **22** (1952) 103-110.

[2] LIFTON, R.J., "Hiroshima and Bursalves", JAMA, vol. **254** (5) (1986).

[3] BAUM, A., GATCHEL, R.J., SCHAEFFER, M.A., "Emotional Behaviour and Physiological Effects of Chronic Stress at Three Mile Island", Journal of Consulting and Clinical Psychology **51** (1983).

[4] CENTER OF THE HISPANIC FAMILY, Psycho-social Consequences of Disasters: The Latin American Experience, Series of Clinical Monographies, No. 2, Chicago (1989).

[5] COHEN, R.E., AHEARN, J.R., F.L.: Handbook for Mental Health Care for Disaster Victims, Johns Hopkins University Press (1980).

[6] LIMA, B.R., Advisory on Mental Health after the Armero Disaster, Colombia, Bol. of Sanit., Panam **101** (6) (1986).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, The International Chernobyl Project: Technical Report, IAEA, Vienna (1991).

[8] RIBALKA, B.B., "Organizasia psijologopedagoguicheskoi pomochi dietiam no base Vniechkolnih uchrezhdeni zona radiologuicheskova kontrolia", The Psycho-social Rehabilitation of Children and Adolescents Victims of Chernobyl, Ukraine Psychological Research Institute, Kiev (1992) 108-118 (in Russian).

[9] DRINEVSKY, N.P., LISENKO, V.I., GOLUBOVA, T.F., POBERSKAYA, V.A., VIRKO, M.D.: "Psijologuicheskoe issledovanie dietei y padrostkov iz zoni Avari no Chernobilskoi AES. V Svizi: Zadachami psijokorrekzi no etape sanatorno-kurortnovo Lichenia", Psychological Research Institute, Kiev (1992) 122-129 (in Russian).

[10] CHINKINA, O.V., Psychological Characteristics of Patients Exposed to Accidental Irradiation in Chernobyl Atomic Power Station, Personal Communication, Oak Ridge Nat. Lab., TN (1991).

[11] BROMET, E.J., Psychological Effects of the Radiation Accident at T.M.I., Elsevier Science Publishing (1991).

[12] DA COSTA NETO, S.B., HELOU, Z., Psicologia na Rehabilitacao dos Radioaccidentados de Goiânia. En simposio Nov. Funleide Goiânia, Brazil (1990) (in Portuguese).

[13] BANDEIRA DE CARBALHO, A., The Psychological Effects of the Goiânia Radiological Accident on the Emergency Responders, Elsevier Science Publishing (1991).

[14] BRANDAO-MELLO C.E., OLIVEIRA, A.R., BANDEIRA DE CARVALHO, A., The Psychological Effects of the Goiânia Radiological Accident on the Hospitalized Victims, Elsevier Science Publishing (1991).

[15] HURTADO, M.R., SECIN, R., MÁRQUEZ, M., RICKS, R.C., BERGER, M.E., The Radiological Accident in Salvador: Psychological Aspects, Elsevier Science Publishing (1991).

[16] CHERNICHEV, A.S., LUNIEV, Y.A., PANOK, V.G., "Monitoring socialno-psijologuicheskoi: abstanovki v reguionah podvergchihsia radioaktivnomu", The Psycho-social Rehabilitation of Children and Adolescents Victims of Chernobyl, Ukraine Psychological Research Institute, Kiev (1992) 66-72 (in Russian).

[17] GONZÁLEZ REY, F.L., Moral Motivation and Self-evaluation of Adolescents and Youngsters, Edit. Científico-Técnica, Havana (1983).

[18] KARNUGINA, A.M., ROZOV, V.U., "Express-ozenka adaptivnosti dietie v exstremalnih usloviah, visvannih posliedstviami avari na Chernobilskoi AES, "The Psycho-social Rehabilitation of Children and Adolescents Victims of Chernobyl, Ukraine Psychological Research Institute, Kiev (1992) 36-45 (in Russian).

[19] NIKULENKO, O.A., TATENKO, E.M, "Abzor zarubiezhnoi literaturi pa problemam psijologuicheskoi pomochi dietiam y padrostkam pastradavchim at ekologuicheskoi katastrofi", The Psycho-social Rehabilitation of Children and Adolescents Victims of Chernobyl, Ukraine Psychological Research Institute, Kiev (1992) 163-169 (in Russian).

[20] Stress psychiczny w sytuacji kryzsu ecologicznego, Pod. Red. A. Bieli y Lublin, Warsaw (1984) (in Polish).

[21] GUILBUX, Y.Z., GONCHARENKO, S.A., "Differenzirovanni podjod k chkolnikam evakuirovannih iz goroda Pripiatz; Tagda y tipier", The Psycho-social Rehabilitation of Children and Adolescents Victims of Chernobyl, Ukraine Psychological Research Institute, Kiev (1992) 148-155 (in Russian).

[22] LORENZO RUIZ, A., REYES VELIZ, A.C., GARCÍA BAJOS, L., HERNÁNDEZ, E.O., PÉREZ LOVELLE, R., "Psychological Characteristics of a Group of Chernobyl Children with Chronic Diseases", in Summaries of the International Conference on Health Psychology, Havana, Cuba (1992) 72.

[23] QUARENTELLI, E.L., Radiation Disasters: Similarities to and Differences from Other Disasters, Elsevier Science Publishing (1991).

[24] ZIRKIN, N.A., "Diagnostika y Korrekzia umstvennavo y sensornovo Razvitia dietei, podvergchihsia vasdietsvia Radiatzi", The Psycho-social Rehabilitation of Children and Adolescents Victims of Chernobyl, Ukraine Psychological Research Institute, Kiev (1992) 73-79 (in Russian).

[25] KIGARCHUK, Z.F., LITNIEVSKAYA M.D., FROLOV, P.D., YURCHENKO, T.R., "Osnovnie napravlenia psijologuicheskoi pomochi dietiam chernobilia v specializirovannom kabinete", The Psycho-social Rehabilitation of Children and Adolescents Victims of Chernobyl, Ukraine Psychological Research Institute, Kiev, (1992) 138-148 (in Russian).

[26] GARNETZ O.N., YAKOBENKO, S.U., "Vliayanie zennostnih orientazi podrostkov Zoni Chernobilskoi Katastrofi na Lichnoe y Professionalnoe samoopredelenie", The Psycho-social Rehabilitation of Children and Adolescents Victims of Chernobyl, Ukraine Psychological Research Institute, Kiev (1992) 100-108 (in Russian).

[27] CHEBIKIN, A., YA. SVISTUNOVA, T.P., VISKOVATOV, Y.; LEKCHEROVA, A.B., Kompleksnoe issliedovanie asobiennostie emocionalnoi sferi dietie, podvergchihsia Vlianiu Avari Chaes", The Psycho-social Rehabilitation of Children and Adolescents Victims of Chernobyl, Ukraine Psychological Research Institute, Kiev (1992) 129-137 (in Russian).

[28] PÉREZ LOVELLE, R., Psyche in Health Determination, Edit. Científico-Técnica, Havana, Cuba (1989).

[29] REYKOVSKI, Experimentalnaya Psijologuia Emocy, Ed. Progress, Moskva. 1979.

[30] LORENZO RUIZ, A., REYES VELIZ, A., GARCÍA BAJO, L., GRAU ABALO, J., "Study of the System of Emotional Relations in a Group of Chernobyl Victims during their Stay in Cuba", Abstracts of Congress on Health Psychology, Havana, Cuba, Oct. 5-9 (1992) 69.

[31] LORENZO RUIZ, A., REYES VELIZ, A., GRARCÍA BAJO, L., "Relationship between Stress and Disease Onset: Study in Chernobyl Adolescents with Chronic Diseases", Materials of the International Seminar of Placentary Hystotherapy in Dermatology, Havana, Cuba, Oct. 23-27 (1995).

[32] GIST, R., LUBIN, B., (Eds), Psychosocial Aspects of Disasters, Wiley, New York (1989).

[33] KARPUGINA, A.M., KARPUGINA, M.B., ZAVADASKAYA, T.V., "Issliedovanie Funksionalnih vosmozhnostie SSS y CNS dietie y podrostikov iz zoni Chotskovo Radiasionnovo Kontrolia", The Psycho-social Rehabilitation of Children and Adolescents Victims of Chernobyl, Ukraine Psychological Research Institute, Kiev (1992) 55-66 (in Russian).

[34] LORENZO RUIZ, A., GRAU ABALO, J.A., MARTIN CARBONELL, M., REYES VELIZ A.C., PUIG ANZORANDÍA P., "Characteristics of Cognitive Processes in Victims of the Chernobyl Accident with Chronic Diseases", Abstracts of Congress on Health Psychology, Havana, Oct. 5-9 (1992) 71.

[35] LORENZO RUIZ, A., CERVERA BAQUERI, G., "Psychological Study of Expectations on the Trip to Cuba of Chernobyl Victims", Abstracts of Congress on Health Psychology, Havana, Oct. 5-9, (1992) 70.

[36] ABREU VASCONCELOS, L, "Algumas caracterísicas da readaptacão de sobreviventes da bomba atómica en Hiroshima", Rev. Psic. Tero. e Pesq. Universidad de Brasilia, **8** 1 (1992) 113-122 (in Portuguese).

[37] RICKS, R.C., BERGER, M.E., O'HARA, F.M., The Medical Basis for Radiation-Accident Preparedness III, The Psychological Perspective, Elsevier Science Publishing, New York (1991).

[38] NAKAJIMA, H., "Catastrophes do no warn. Let us be prepared", World Health, **1** (1991).

CONTRIBUTORS TO DRAFTING AND REVIEW

PRINCIPAL AUTHORS

Cárdenas, J.	Centre for Radiation Protection and Hygiene, Cuba
Cruz, R.	Centre for Radiation Protection and Hygiene, Cuba
García, O.	Centre for Radiation Protection and Hygiene, Cuba
Jova, L.	Centre for Radiation Protection and Hygiene, Cuba
Valdés, M.	Centre for Radiation Protection and Hygiene, Cuba

CONTRIBUTING AUTHORS

Arado, O.	Centre for Radiation Protection and Hygiene, Cuba
Lamadrid, A. I.	Centre for Radiation Protection and Hygiene, Cuba
López, G.	Centre for Radiation Protection and Hygiene, Cuba
Morera, L.	Centre for Radiation Protection and Hygiene, Cuba

CONTRIBUTORS TO REVIEW

González, A.	International Atomic Energy Agency
Inkret, W.C.	Los Alamos National Laboratory, United States of America
Kerekes, A.	Institute for Radiobiology and Radiohygiene, Hungary
Nénot, J.C. (Chairman)	Institut de protection et de sûreté nucléaire, France
Oliveira, A.R.	Industrias Nucleares do Brasil, Brazil
Seyama, T.	Radiation Effects Research Foundation, Japan

PARTICIPANTS

Araico, E.	Dept. of Environmental Radiological Surveillance CNSNS, Mexico
Delgado, R.	Centre of Studies Applied to Nuclear Development, Cuba
Domene, M.M.	Hospital General Gregorio Marañón, Spain
Esvarch, E.	William Soler Paediatric Hospital, Cuba
Grandio, O.	William Soler Paediatric Hospital, Cuba
Llanes, R.	Tarará Paediatric Hospital, Cuba
Lonchong, M.	J.M. Márquez Paediatric Hospital, Cuba
Manzano, J.	Centre for Radiation Protection and Hygiene, Cuba
Nogueira de Oliveira, C.	Institute of Radioprotection and Dosimetry, Brazil
Prieto, M.J.	Hospital General Gregorio Marañón, Spain
Valdés, A.	Tarará Paediatric Hospital, Cuba
Villa, R.	Centre of Isotopes, Cuba