

**SUMMARY REPORT OF “RISK ASSESSMENT OF CHERNOBYL ACCIDENT CONSEQUENCES: LESSONS LEARNED FOR THE FUTURE” CCMS PILOT STUDY MEETING, KIEV, JUNE AND ROME, 2005** (at care of Giovanni A. Zapponi and Dimitri Bazyka)

This report presents a synthesis of the contributions by Pilot Study participants. In the first part (at care of G.A. Zapponi), some items concerning health effects are discussed, that provide some relatively new information. In the second part (at care of Prof. D. Bazyka) other aspects, equally important, are summarized concerning neurological and psychological effects, managed in the medical response to the accident, and other related topics.

**PART 1: SOME MAIN HEALTH EFFECTS**

**1) CHERNOBYL ACCIDENT EFFECTS (UKRAINE): AN UPDATE** (Prof. D. Bazyka)

Three main points were underlined for population protection from Chernobyl accident consequences: i.) Radiation Protection, ii.) Social Support and iii.) Health Care. Hereafter, some updated data concerning some main points were summarized:

Over 237 patients with ARS (Acute Radiation Syndrome) diagnosed in 1986, 137 of whose were confirmed in 1989, 28 died in 1986 and other 29 in the follow up 1987-2004 period (8 due to sudden cardiac death, 11 due to oncological and oncohematological diseases, 4 to traumas and accidents, and 6 to somatic or nervous diseases or to infections).

The cancer incidence (SIR) update has shown thyroid cancer rates 8- and 6-fold higher than national data (control) respectively in radiation rehabilitation workers and in the evacuees from Prypyat and 30-kilometer exclusion zones (highly contaminated). For other solid cancers and leukemia some uncertainty level remains in the expert opinions (however, in part reduced by recent studies presented in the workshop).

The cardiovascular disease mortality risk resulted in an ERR (Excess Relative Risk) of 0.54 per Gy ( $5.4 \times 10^{-4}$  per mGy) based on the 60,910 cohort of Russian emergency workers (Ivanov et al., 2000). This EER is higher than the one estimated from the atomic bomb survivor cohort (ABS), which is in the order of 0.17 per Gy; however 95% confidence intervals overlap. Over 4995 deaths, 1728 were due to cardiovascular diseases, proportion much higher than the normal one. The conclusion is that low-dose whole body irradiation ( $\geq 0.05$ Gy) may represent a risk factor for ischemic heart diseases, cardiomyopathy, and cerebrovascular diseases.

The risk of cerebrovascular diseases was significantly higher in the over 500 mSv exposure group, in comparison with the less than 100 mSv exposure group.

The highly exposed “liquidators” who recovered from the acute radiation syndrome (ARS) are considered as likely at increased cardiovascular disease risk.

In conclusion, the Chernobyl accident data indicate an excess of cardiovascular and cerebrovascular disease risks consistent with the ones assessed for ABS (Atomic Bomb Survivors). Further investigations are however considered important.

**1. 2) RISK OF MALIGNANT TUMOURS OCCURRENCE IN CRITICAL GROUPS OF THE UKRAINIAN POPULATION AFFECTED AFTER THE CHERNOBYL ACCIDENT** (Prof. A. Prsyazhnyuk, Dr. V. Gristchenko, Dr. M. Fuzik And Dr. K. Slipenyuk)

The population examined in this descriptive study includes the Chernobyl accident recovery workers operating in the 1986-1987 (1990-2002 observation period, 1107298 person-years), the evacuees from Prepay town and from the 30 km zone (from the nuclear plant) (1990-2002 observation

period, 678725 person-years) and the residents in most contaminated Ukraine territories (5 districts, 1980-2003 observation period, 4863074 person-years). As a whole, 14285, 4282 and 1754 cancers were respectively diagnosed in residents of contaminated territories (1980-2003), in the recovery worker sub-cohort (1990-2002) and in the evacuees (1990-2002).

### General exposure

For the recovery workers, the average individual dose equivalent varied between 100 and 200 mSv in 1986 and from 50 to 100 mSv in 1987.

For the evacuees from Prypyat town, the average external dose was evaluated as 10-12 mSv; for this category, the average external dose estimates should be doubled to account for the internal dose component.

According to general dosimetric “passportisation”, residents of the most contaminated areas received an individual effective equivalent average dose of 17.4 mSv.

### Thyroid exposure

A comprehensive information on thyroid doses for recovery workers is not available.

The high thyroid dose (0.98 Sv – 1.4 Sv) in children resident in contaminated territories is remarkable particularly if compared with those of adults (0.187 Sv – 0.221 Sv).

The total collective dose in evacuees was 2996 person- Sv and the average individual dose was 0.33 Sv.

The average dose was clearly depending on the age at the accident time: 0.86 Sv and 0.18 Sv, respectively in the 0-15 and in >16 year groups.

### All Cancers

In the 1980-2003 period, the incidence of all cancers in the most contaminated territories is characterized by a smooth increase with time. It is worthwhile noticing that there was a considerable difference among the incidences assessed in the initial period in the whole Ukraine, in Kiev region, in Zhytomir region and in contaminated territories. The regression coefficients ( $b \pm SE(b)$ ) of cancer incidence time evolution (average annual increase of incidence rates) are:

Ukraine:  $1.45 \pm 0.30$

Kiev region:  $2.22 \pm 0.17$

Zhytomir region:  $2.03 \pm 0.40$

Contaminated territories:  $1.23 \pm 0.55$

These tendencies were similar for male and female sub-populations.

### All Cancers: Standardized Incidence Ratios

Observed Groups (observation period)	Observed cases	Expected cases	SIR (%)	95% C.L.
Contaminated areas				
Residents (1990-2003)	7487	9249.8	80.94	79.1 - 82.8
Recovery operation				
Workers (1990-2002)	4282	3436.3	124.6	120.9 - 128.3
Evacuees from 30 km				
Zone (1990-2002)	1754	2175.2	80.6	76.9 - 84.1

These data indicate that only in the recovery workers the all cancer incidence was significantly higher than the national one, while in the other two groups it was significantly lower.

It is also important to consider the analysis of the specific trends for specific territories, that indicates

an increase with time during the 1980-2003 period, higher in the most contaminated areas.

### Thyroid cancer

As known, thyroid cancer represented the most evident and important effect among the various categories of malignant tumors related with radiation exposure. Some increase of this pathology was noted since 1987-1990, possibly in part due also to a screening effect; since 1992, a dramatic increase of thyroid cancer was observed. The estimated regression coefficients ( $b \pm SE(b)$ ) of the incidence increase with time are (average annual increase of incidence rates):

Ukraine:  $0.12 \pm 0.01$   
 Kiev region:  $0.49 \pm 0.05$   
 Kiev city:  $0.50 \pm 0.05$   
 Contaminated territories:  $0.44 \pm 0.08$   
 Zhytomir region:  $0.19 \pm 0.03$

The time-related increases for “contaminated regions”, and for the Kiev region and the Kiev city (in the areas where about 80% of former residents were evacuated) are similar, and considerably higher than the other ones and, in particular, than the one of whole Ukraine.

### Thyroid Cancer: Standardized Incidence Ratios

Observed Groups (observation period)	Observed cases	Expected cases	SIR (%)	95% C.L.
Contaminated areas				
Residents (1990-2003)	156	102.0	152.9	128.9 – 176.9
Recovery operation				
Workers (1990-2002)	121	16.2	746.2	613.3 – 879.6
Evacuees from 30 km				
Zone (1990-2002)	136	28.3	480.3	399.6 – 561.1

These data indicate thyroid cancer incidences higher than the national ones for residents in the contaminated areas (~1.5 folds), for recovery operation workers (~7.5 folds) and for the evacuees from the contaminated areas (~4.8 folds).

### Quantitative estimates of radiation risks of thyroid cancer

In the residents of contaminated territories, the only statistically significant risk was assessed in children (0 – 15 year aged at the accident time), with an Excess Absolute Risk (EAR) of  $1.7 \times 10^{-4}$  Py-Sv (95% C.I:  $1.1 \times 10^{-4} - 2.2 \times 10^{-4}$ ), an Excess Relative Risk (ERR) of 15/Sv (CI: 9.8/Sv – 20.2/Sv), and an Attributable Risk (ATR) of 89.0%. For residents aged more than 15 years, the EAR was  $0.3 \times 10^{-4}$  Py-Sv (C.I:  $-0.3 \times 10^{-4} - 0.8 \times 10^{-4}$ ), the ERR was 0.5/Sv (CI: -0.5/Sv – 1.5/Sv), and of an Attributable Risk (ATR) of 9.8%.

In the recovery workers (males aged > 25years), the calculations based on the external dose indicated an EAR of  $6.1 \times 10^{-4}$  Py-Sv (CI:  $4.7 \times 10^{-4} - 7.5 \times 10^{-4}$ ) an ERR of 23.3/Sv (CI 18.0/Sv - 28.7/Sv) and an ATR of 77.8%.

In the evacuees, for children (0-15 years at the accident time) the EAR was  $2.8 \times 10^{-4}$  Py-Sv (CI:  $1.5 \times 10^{-4} - 4.1 \times 10^{-4}$ ), the ERR was 40.8/Sv (CI: 21.9/Sv – 59.6/Sv) and the attributable risk 97.2%. For evacuees aged more than 15 years at the accident time, the EAR was  $7.5 \times 10^{-4}$  Py-Sv (CI:  $5.6 \times 10^{-4} - 9.4 \times 10^{-4}$ ), the ERR was 13.1/Sv (CI: 9.8/Sv – 16.5/Sv) and the attributable risk 70.8%.

## Female Breast Cancer

The estimated regression coefficients ( $b \pm SE(b)$ ) of the incidence increase with time are (average annual increase of incidence rates):

Ukraine:	$0.62 \pm 0.04$
Kiev region:	$0.64 \pm 0.07$
Zhytomir region:	$0.70 \pm 0.06$

Contaminated territories:  
1980-2003:  $0.89 \pm 0.17$

### Female Breast Cancer: Standardized Incidence Ratios

Observed Groups (observation period)	Observed cases	Expected cases	SIR (%)	95% C.L.
Contaminated areas				
Residents (1990-2003)	404	251	160.8	145.1 – 176.5
Female recovery operation				
Workers (1990-2002)	145	75.1	193.1	161.7 – 224.5
Evacuees from 30 km				
Zone (1990-2002)	150	95.8	156.6	131.5 – 181.7

Because of territorial variation of breast cancer incidence in the Ukraine, the SIR was calculated on the base of two standards (local 1980-1991, recovery workers and national 1998, others)

These data indicate a significant incidence of breast cancer in both female recovery workers and contaminated territory residents. The case of evacuees is controversial, because its significance is not confirmed if the 1998 local standard is used as reference.

It is however worthwhile noticing that the IARC (2006) study on breast cancer, hereafter discussed, confirms a breast cancer incidence increase in women resident in the Kyiv and Zhytomir regions of Ukraine.

## Conclusions

The main effect of ionizing radiation exposure caused by the Chernobyl accident is a significant absolute, relative and attributable risk of thyroid cancer in the evacuees from Prypyat town and the 30 km zone, in Chernobyl accident recovery workers and in residents of contaminated territories. The risk estimates were in the range estimated by other researchers.

A significant increase of all forms of cancer incidence rate in comparison with the national one was only observed for recovery operation workers active in 1986-1987.

There is the indication of an increase of breast cancer incidence in women participating to recovery operation works in the 1986-1987 period and in women sub-population still living in most contaminated areas.

Taking into account the differences among the latency periods of various cancer categories, special attention should be given also to lung, stomach, colon and ovary cancers and to multiple myeloma that past experience indicates to be associated to radiation exposure.

### 3) IARC STUDIES OF CANCER RISK FOLLOWING CHERNOBYL ACCIDENT: PROGRESS AND RESULTS. (DR. A. KESMINIENE)

The cooperation with the International Agency for Research on Cancer (Lyon) has been and is very important for the Pilot Study. The first results of the case-control studies by IARC, Belarus and Russia of thyroid cancer among the young people in Belarus and Russia have allowed establishing a causal relationship between the exposure to radioactive iodines and the increased risk of thyroid cancer in those exposed as children or young people. The studied population included all the people in Gomel and Mogilev “oblasts”, who were children (<15 year) at the accident time, as well as the people in Bryansk, Kaluga and Tula oblasts in Russia who were children or adolescents (up to 18 year) at the accident time. The dose reconstruction included inhalation and ingestion exposure to  $^{131}\text{I}$  during the first weeks after the accident, the internal doses from the inhalation and ingestion intake of short lived iodine ( $^{132}\text{I}$ ,  $^{133}\text{I}$  and  $^{135}\text{I}$ ) and tellurium ( $^{131\text{m}}\text{Te}$ ,  $^{132}\text{Te}$ ) in the first days after the accident, and, for a much more extended time period (until the diagnosis), from Cesium ( $^{134}\text{Cs}$  and  $^{137}\text{Cs}$ ).

The assessed dose distribution, used for the study, respectively indicated a median level of about 356 mGy and a maximum level of 9528 mGy for Belarus and a median levels of about 39.4 mGy and a maximum level of 5257 mGy for Russia, while for the short lived iodine and tellurium the median and maximum levels, assessed in the study, are 1.6 mGy and 534 mGy (Belarus) and 0.1 mGy and 26 mGy (Russia).

For external exposure, the assessed median and maximum levels are 2.4 mGy and 98 mGy (Belarus) and 0.9 mGy and 31 mGy (Russia), and, for short-lived radio-nuclides, 1.2 mGy and 42 v (Belarus) and 0.4 mGy and 12 mGy (Russia). The estimated median and maximum total doses are 365 mGy and 10163 mGy (Belarus) and 40.4 mGy and 5314 mGy (Russia). The statistical distribution of these doses is log-normal-like, with maximum levels much higher than the median ones.

The resulting dose-response relationships indicated a shape substantially compatible with the linear hypothesis, and the use of logistic regression (excess relative models and log-linear models) led to substantially compatible estimates (overlapping confidence limits) of the OR at 1 Gy:

- For excess relative risk models, ORs from 4.9 (95%CI: 2.2 to 75.) to 6.6 (95%CI: 2.0 to 11.1)
- For log-linear risk models ORs from 5.5 (95%CI: 3 to 9.5) to 8.4 (95%CI: 4.1 to 17.3);

The higher OR values are obtained by linear models (excess relative risk and log-linear risk).

The estimated OR at 1 Gy for different radiation types range from 5.2 (95%CI: 2.2 to 8.2) for  $^{131}\text{I}$  to 5.9 (95%CI: 1.6 to 10.2) for all iodine isotopes.

Moreover, the influence of iodine in soil, reflecting the iodine natural bio-availability for the involved population at the time of the accident, and of the stable iodine supplementation has been analyzed. This has allowed estimating the OR at 1 Gy in relation to soil iodine level and iodine supplementation:

In the absence of potassium iodide consumption:

- At the highest two tertiles of soil iodine: OR = 3.5 (95%CI: 1.8 to 7.0)
- At the lowest tertile of soil iodine: OR = 10.8 (95%CI: 5.6 to 20.8)

In the presence of sodium iodide consumption:

- At the highest two tertiles of soil iodine: OR = 1.1 (95%CI: 0.3 to 3.6)
- At the lowest tertile of soil iodine: OR = 3.3 (95%CI: 1.0 to 10.6)

In the Pilot Study discussion, these latter data were considered of main interest for emergency planning in similar conditions. In particular, the indication that the sodium iodide administration could not guarantee a total protection for populations with a low natural assumption of iodine is worthwhile of attention.

As underlined by the authors, this is the largest case-control study of thyroid cancer in young people. As a general observation by the Pilot Study group, the analytical epidemiological studies, as the one here discussed, are essential to assess the effects and risks and are more powerful than the geographical studies, which however, are much less costly and time requiring.

Dr. Kesminiene also presented the results of a descriptive IARC study of spatial and temporal trends in breast cancer incidence in contaminated regions of Belarus and Ukraine, to be considered as preliminary at the workshop time. This study has been recently published (after the Pilot Study meeting, Pukkala et al., 2006). A significant two-fold risk increase was observed in women resident in the in the most contaminated districts (Gomel and Mogilev regions of Belarus and Kyiv and Zhitomir regions of Ukraine) compared with the least contaminated districts (Relative Risk: 2.24 , 95% CI 1.51-3.32, Belarus; 1.78, 95% CI 1.51-3.32, Ukraine). The increase was highest for women who were younger at the exposure period.

The time trend of breast cancer Relative Risk (RR) by categories of cumulated exposure in the most contaminated territory of Belarus and Ukraine has been estimated, indicating a significant relative risk increase at exposure levels  $\geq 40$  mSv, doses lagged by 5 years for women aged less than 45 years in 1986. A formal analytical epidemiological study on breast cancer risk in young women in Belarus and Ukraine, aimed at estimating the interactions between radiation, genetic predisposition and other factors will be carried out.

In any case, the results obtained, which are compatible with the ones reported by Prysyzhnyuk et al. (section 2), clearly suggest that the emergency response planning in similar conditions needs to take into account specific protection measures for the exposed women.

#### **1.4) STUDY ON LEUKEMIA AND OTHER HEMATOLOGICAL DISEASES IN THE RECOVERY WORKERS IN UKRAINE AFTER THE CHERNOBYL ACCIDENT (Prof. A.E. Romanenko et al.; Ukraine and US (NIH) Cooperation)**

This research has used a case-control design to investigate leukemia incidence in rehabilitation workers in Ukraine, based on cancer registry data. The dose-response relationships in recovery workers, the possible confounding factors, the influence of the time periods of exposure and of the age at exposure, and the different relevant hematological effects have been investigated. The exposure was assessed using the available official dose registers, retrospective methods (EPR, FISH) and other related procedures. The medical data and, consequently, the incidences, were revised and confirmed by international expert commissions. At the moment of the Pilot Study meeting, the exposure doses were reconstructed for 462 individuals.

- For the cases, the exposure assessment indicated an average level of 181.5 mGy (standard deviation 519 mGy) and a geometric mean of 20 mGy (geometric standard deviation 12.4), dose

range: 0.003 – 3187 mGy.

- For the controls, the exposure assessment indicated an average level of 78 mGy (standard deviation 217 mGy) and a geometric mean of 11.5 mGy (geometric standard deviation 10.5), dose range: 0.005 – 3256 mGy.

The results at the moment available on the effects in recovery workers indicate:

For CLL leukemia:

- For an exposure range  $\geq 100\text{mGy}$ , OR = 2.15 (95%CI: 1.00 to 4.58)
- For an exposure range  $\geq 200\text{mGy}$ , OR = 2.04 (95%CI: 0.76 to 5.28.)
- For an exposure range  $\geq 250\text{mGy}$ , OR = 1.81 (95%CI: 0.57 to 5.35)

For the other leukemias:

- For an exposure range  $\geq 100\text{mGy}$ , OR = 2.04 (95%CI: 0.86 to 4.77)
- For an exposure range  $\geq 200\text{mGy}$ , OR = 2.14 (95%CI: 0.73 to 5.98)
- For an exposure range  $\geq 250\text{mGy}$ , OR = 2.39 (95%CI: 0.74 to 7.28)

As stated by the authors, the preliminary analysis of the obtained data demonstrates some increase of leukemia risk in the recovery workers who have been irradiated at doses over 100mGy. It was observed that an increase of the statistical power of the study and more closely examined statistical analysis were necessary for a more detailed evaluation.

In the National Report of Ukraine, distributed in the 24<sup>th</sup> -26<sup>th</sup> April 2006, at the International Conference in Kiev “20 Years after Chernobyl Accident. Future outlook”, a significant leukemia increase in recovery workers is reported, based on this study and on further data that it has produced.

### **1.5) DEMOGRAPHIC LOSSES OF THE POPULATION OF UKRAINE IN CONNECTION WITH THE CHERNOBYL CATASTROPHE (N. Omelyanets)**

This study was aimed at the quantitative definition of the demographic losses of the population on territories of Ukraine affected by the accident consequences. The populations living in the most contaminated districts (Zhitomir, Kiev) and in close territories (Ludiny, Narodichy, Ovruch, Ivankov, Poleskoe), as well as the populations living in non-contaminated territories (Poltava and Lockchvitsya territories) and the whole Ukrainian population were examined.

- As a whole, the reported whole number of people in Ukraine is about 50 millions in 1979, about 52 millions in 1994 and about 48 millions in 2003.
- A considerable progressive reduction in the birth rate in the most contaminated areas has been observed. In 1985-1986, the birth rate was something more than 13 -15 births/year per 1000 women in fertility age; in 2002-2003, this rate was reduced to about 7-10 births/year per 1000 women in fertility age, in particular due to a decrease after 1988.
- A considerable progressive increase of population mortality was also observed in the most contaminated areas in the same period, with a rate of less than 13-15 deaths per 1000 per year in 1985 and of about 17-20 per 1000 per year, in particular due to an increase mostly taking place after 1989.
- Cancer diseases accounted for a limited fraction (21%) of the population loss after the accident.

- In all the investigated territories, the highest fraction of mortality increase was in the age group of 60 years and higher.

Even if these effects may be in part attributed to general difficult conditions of Ukraine, these data highlight a critical social condition in the most contaminated areas after the accident and suggest that the accident consequences stimulated women to reduce births and increased the mortality rate of elderly people.

### **1.6) GENETIC INSTABILITY IN CHILDREN BORN IN THE FAMILIES OF THE CHERNIBYL ACCIDENT CLEAN-UP WORKERS (Prof. Ye. Stepanova and Prof. Ye. Skvarkaya)**

The study was aimed at investigating the health status and the possible genetic effects in children born to liquidator families, based on the medical-statistical data of the State Register of Ukraine on congenital abnormalities in children. This register includes the data of 13136 children, born in families of “liquidators” active in 1986. Among them, 1190 cases of congenital disorders (mainly in the osteo-muscular, cardiovascular, genitourinary) were identified (around 9%), with the higher frequency in the ones born in the first years after the accident.

In a second stage of the study, the health status of children of 24 liquidators who were affected by ARS, of 380 liquidators active in 1986, exposed at doses  $\geq 25$  cSv, of 628 liquidators and evacuated people, exposed at doses  $\leq 10$  cSv, of 509 persons living in territories with contamination levels of 555 kB/m<sup>2</sup> and more, and, lastly, of 706 persons living in non contaminated territories. In the children of the first and second groups (ARS and  $\geq 25$  cSv exposure) the frequencies of multiple stigmas resulting from the register respectively were about 58% and 26%, while they were about 9% in the control group, with a significant difference. The children of mostly exposed parents (ARS,  $\geq 25$  cSv and residents in territories with 555 kB/m<sup>2</sup> and more contamination levels) resulted characterized by a decreased adaptation capability to the external environment, by a higher susceptibility to somatic pathology and to increased morphogenetic variants.

In a third phase, 297 families were examined, that included a “liquidator” father, exposed at doses ranging from 10 cSv up to 100 cSv, a substantially not exposed mother, and two children, one born before the accident (“sib”) and the other after it (“proband”). The control group consisted of 97 families in which parents and children were not exposed. The children conceived and born after the father activity as recovery worker appeared to have poorer health parameters in comparison with their elder brothers and sisters born before the accident and reduced adaptation capacities to the external environment.

Lastly, a sample of children conceived after parental exposure to radiation (highly exposed “liquidators”, whose large majority participated to the cleaning activity starting in April 1986) was screened for the appearance of new fragments in multi-site DNA fingerprinting, using as internal control group the children conceived before such exposure; external controls (children of non-exposed families) (joint study of Ukraine and Israel researchers). A high increase of in the number of new bands was found in the DNA of children conceived after the father exposure, in comparison with the control group. Considering that the environmental exposure could be assumed to be comparable for both the children conceived after and before the father exposure, the difference has been assumed to be due to changes in the germ-line cells. It is worthwhile noticing that the hereafter mentioned World Health Organization Pilot Project on Brain Damage *in-utero* under the auspices of the International Program on the Health Effects of the Chernobyl Accident (IPHECA) has indicated an increase of mild mental retardation and an upward trend of behavioral disorders in prenatally irradiated children in comparison with the control group, with some agreement of part of effects found in the study above discussed.

The results of this study are confirmed and reported in the National Report of Ukraine (2006): “20 years after Chernobyl Accident. Future Outlook”.

### **1.7) IMPLICATIONS OF THE VARIABILITY OF THE CONTAMINATION LEVELS AND OF EXPOSURE AND DOSE LEVELS RELEVANT TO EPIDEMIOLOGICAL ASSESSMENT** (Giovanni A. Zapponi)

A very high variability in the measured levels in soil and other substrata contamination, as well as in the assessed exposures and doses to the general population, has been pointed out by many studies on the territories mostly affected by the Chernobyl accident consequences. In the large majority of cases, the statistical distribution of the measured or assessed levels appears to be a log-normal-like one. As well known, this kind of distribution is asymmetrical, with an extended tail towards high values, with a high frequency of considerably lower values. This emerges from exposure and dosimetric data presented in the UNSCEAR (2000) document, and from some fundamental studies on the population exposure (e.g., Golikov et al., 2002; Likhtarev et al., 2002).

These aspects are important in the evaluation of epidemiological study results concerning the Chernobyl accident related risks.

The UNSCEAR document of the year 2000 presents a table (8) of the estimated  $^{137}\text{Cs}$  deposition from the accident over a global area of about one million of  $\text{km}^2$ , with average levels varying from  $12 \text{ kBq/m}^2$  (over a sub-area  $654200 \text{ km}^2$ ) to  $2200 \text{ kBq/m}^2$  (over a sub-area of  $3110 \text{ km}^2$ ). The area with the highest level of contamination ( $2200 \text{ kBq/m}^2$  as an average) was about the 0.3% of the whole, while the mean deposition was  $\leq 83 \text{ kBq/m}^2$  on the 97% of the whole territory. It is immediately evident that, in the presence of a distribution like this, a random and numerically limited sampling would not have a statistical power sufficient for the identification of the most critical levels. This observation holds for most of the available data on environmental levels and exposure, also including the exposure data presented above.

The suggestion by Likhtarev et al. (2002), based on the extremely high variability of exposure levels, that the “critical” group (highest exposure group) deserves particular social and medical attention, also holds for epidemiological evaluation.

In fact, if the monotonic increasing exposure-effect trend assessed for radiation risk (e.g., linear or linear-quadratic model) is assumed, this variability will be reflected in the risk, and, in the case of linear-quadratic trend, the risk variability will be higher.

This suggests that geographical or descriptive studies not appropriately considering this statistical distribution will have limited, or very limited, statistical power for detecting a possible risk increase taking place in very small percentage of territory, highly contaminated, or in a very small percentage of population, highly exposed. As already mentioned, the “critical groups” need a particular attention, and their condition should not be “diluted” in larger groups. What is commonly defined as  $\beta$  or type II error (probability of accepting the “Null Hypothesis” when it is not “true”, i.e., of attributing to chance a real result) could be considerably great. Computer simulations clearly show this.

As a consequence, analytical epidemiological studies are of main importance for better analyzing the Chernobyl accident consequences. This is confirmed by the new evaluations emerging from case-control studies recently carried out, which have indicated risk conditions not well identified in the past. Lastly, a conservative approach will be appropriate in the data evaluation, taking also into account the level of the possible  $\beta$  error and the statistical power of the carried out studies.

## **1.8) A REVIEW OF UKRAINIAN DATA: LESSONS LEARNED AND A MODEL OF RADIATION CONTAMINATION EVENT AND OF RELATED PROBLEMS (Prof. D. Bazyka)**

The history of Chernobyl accident emergency response indicates that 237 people were heavily exposed, about 600,000 people (“liquidators”) were exposed at a medium-high level, and up to 15,000,000 people were exposed at low level, while tens of millions of people, exposed to ultra low levels were affected by psycho-emotional stress. For each of these groups’ specific treatments and support was necessary. This experience may be useful for the emergency response to in analogous conditions, also including the impact of an improvised nuclear device.

For instance, the lessons learned from the first stage after the accident indicate the need of timely affording a possible event with hundreds of people heavily exposed to significant acute radiation injures, who require immediate and specialized care. Moreover, the possibility of more than 100,000 people less exposed and requiring adequate treatment should be considered.

Other aspects include the monitoring of environment and food products, the restriction of access in the most contaminated areas, interruption or countermeasures in agricultural production, and other analogous actions.

The Chernobyl event has also indicated the inability or difficulty of an immediate estimation of the whole radiation situation, even if the timely evacuation of highly exposed people and their immediate transport to the Moscow and Kiev hospitals enabled specialized effective treatments.

The initial protective action decisions included the immediate evacuation of people at significant risk (which implies appropriate decision criteria) and the interdiction of access to specific identified territories (which implies appropriate contamination monitoring data). The use of potassium iodide was critical in preventing thyroid uptake of radioactive iodine in contaminated areas. It is worthwhile noticing that the efficiency of this treatment sharply decreases after exposure (available experience indicates that the protection efficiency is only about a 7% after 24 hours from exposure). Therefore, whenever necessary, this treatment needs to be immediate; this has to be considered in emergency planning (KI availability, immediate distribution, people information, etc.).

Official data on Chernobyl accident indicate that iodine prophylaxis started in the highly contaminated Prypyat town (at less than 3 km from the nuclear plant) on April 26<sup>th</sup> 1986, 10 hours after the accident, and that it was significantly delayed in the large number of other residential areas. The difficulties encountered may be easily understood, if it is considered that iodine prophylaxis was provided as a whole to 5 million people, including 1.6 million children.

Moreover, at the very beginning, no radio-protective drugs were used before entering into the contaminated areas (treatments included hemosorbition, enterosorbents, immuno-modulators, other). The immediate availability of adequate resources and of procedures for rapid distribution of these and other drugs is another essential point.

As far as the sheltering procedures and levels are concerned, the information distribution of protection requirements was diffused with some delay in Prypyat town. To other involved populations groups, including Kyiv town, recommendations on sheltering were distributed on May 10<sup>th</sup> 1986 (two weeks after the accident). Finally, the sheltering efficacy could not be appropriately assessed.

The first decisions concerning the population evacuation from Prypyat town were taken on the accident day (April 26<sup>th</sup> 1986), based on measurements effected in some parts of the town, indicating dose rates up to several mSv/hour. After 9 p.m. on the same day, 1,350 city buses, 2 railway trains and 3 motor ships were brought into the Chernobyl district. At 10 p.m., the USSR Ministry of Public Health decided evacuate the town. The evacuation of 49,360 and 254 people, respectively from Pripjat town (including 17,000 children and 80 bed-bound patients) and from Yanow railway station was carried out in the following day (April 27<sup>th</sup> 1986) between 2 p.m. and 5 p.m.. It is worthwhile mentioning that the

city buses were contaminated during their presence in the evacuation areas, and consequently caused some contamination in the Kyiv town after their return.

Before the beginning of May (i.e., 4-5 days after the accident) the radiation contamination conditions were assessed up to a 1000 km distance from nuclear plant, based on aerial surveys, mobile radiological laboratory measurements and radiometric prospecting. During the first phase, 50,000 cesium, 2000 radio-iodine and 600 “hot particles” measurements were carried out. Thyroid gland radioactivity was directly measured on 152,000 individuals and total body radioactivity on 200,000 individuals were carried out. For evacuees, 56,000 dose measurements were made, and “dosimetry passports” were distributed for 1200 settlements.

The evacuation from the other neighboring areas was carried out between May 2<sup>nd</sup> and May 7<sup>th</sup> 1986. The decision criteria were based on the 0.05 mSv/hour limit for the isopleths of residential areas, where the estimated exposure doses could exceed 0.1 Sv during the first year after the accident (USSR Ministry of Public Health). The recommended intervention levels for temporary relocation and permanent resettlement respectively were 30 mSv in one month and 1 Sv in lifetime. In some cases, the selection of population relocation areas was not optimal, and led to some exposure increment because of additional exposure to natural radioactivity (e.g., high radon release).

The countermeasures for the external exposure reduction, adopted in the first period after the accident, with many short-lived gamma emitters still active, included the removal of soil top-layer in the mostly frequented places of the highly contaminated areas, the cleanup of buildings, the replacement of contaminated roofs and constructions, the asphaltting of roads, and other analogous actions. It is worthwhile noticing that the clean-up of school areas was the most effective action, leading to a measured 30% reduction of the external exposure. In 1986, a daily washing of roads, pavements and yard was effected in urban areas (25 km<sup>2</sup> in Kyiv) and dead leaves were removed and buried (in Kyiv, 323,000 m<sup>3</sup>). When carried out in rural settlements, analogous actions did not produce significant results. Lastly, it has been estimated that total effectiveness of these countermeasures led to a limited external dose reduction. However, these countermeasures were highly effective in reducing population anxiety (but not in all cases), even in areas with low exposure doses. The Chernobyl experience indicates that the planning and the efficiency of these activities might be improved.

The countermeasures for internal exposure dose reduction were significantly more efficient. In fact, more than 50% of internal dose in the Ukrainian contaminated areas was due to radioactive cesium in milk, so that the substitution of local milk and other food items with external and “clean” ones led to a considerable internal dose reduction. As an example, evaluations carried out on the Dubrivitsky region of the Rivne oblast indicate an 11-fold reduction in internal dose as consequence of local food consumption restrictions, in comparison with expected level in the absence of countermeasures.

The recommended generic intervention levels for temporary relocation and permanent resettlement were:

Actions	Avertable doses
• Initiating temporary relocation	30 mSv in 1 month
• Terminating temporary relocation	10 mSv in 1 month
• Permanent relocation	1 Sv lifetime

Personnel of Shelter that are or will be involved in works at risk (30-km zone) during 2004-2008 years include about 14,000 people (radiation workers of Chernobyl, the nuclear industry staff and volunteers with no previous exposure. The involved areas could not be brought into compliance with the international safety standards and the Ukrainian national regulation.

In the past recovery action, working areas included “hot cell” conditions (presence of open sources). The problems were a permanent external exposure, a high risk of radio-nuclide inhalation and of their incorporation through cuts or wounds, a severe psychological stress, a possible synergism of radiological and general industrial risk. These points need attention.

The possible conclusions are:

- Chernobyl experience in radiation protection has to be reassessed and implemented in emergency planning.

The most important items include:

- Late effects after acute radiation syndrome.
- Leukemia, thyroid, breast, colon, lung, and bladder cancers in exposed recovery workers and populations.
- Analysis of integrated cancer databases on general population.
- Mortality from cardiovascular diseases in radiation workers.
- Follow-up studies of Shelter workers.

## **PART 2. NEUROLOGICAL AND PSYCHOLOGICAL EFFECTS, LESSONS LEARNED IN THE MEDICAL EMERGENCY RESPONSE, IMPROVED RETROSPECTIVE DOSIMETRY**

### **2.1 NEUROLOGICAL AND PSYCHOLOGICAL EFFECTS (Prof. D. Bazyka)**

Frequency of mental retardation cases among children exposed *in utero* is the subject of several studies in Ukraine and Russia: A study performed in the frame of IPHECA project was criticized for inappropriate control groups and usage of non-standard psychological scales. At present, a registry is being developed of children irradiated *in utero* in Prypyat. Neuro-psychological disorders of children, who received acute pre-natal exposure with doses of 10,7-92,5 mSv on the fetus and 0,2-2,0 Gy on the thyroid gland of the fetus, are heterogeneous. Preliminary results of those exposed *in utero* have demonstrated tendencies of increased behavioral and emotional disorders. The frequency of neuropsychological disorders among parents of children exposed *in utero* is higher than in a control group. The impact of Chernobyl accident factors other than irradiation has to be determined.

A number of radiation related non-cancer endpoints are of concern following the Chernobyl accident. Among them, the development of cataracts in clean-up workers and others who may have received significant exposures. There are sound indications that the incidence of cardiovascular, cerebrovascular and thyroid diseases in clean-up workers and possibly other non-cancer conditions may be increased; radiation exposure or other factors may play a role in this increase. Further investigations are needed. During 18 years after the accident other types of health effects seem to have emerged. These are primarily neuropsychiatric and cardiovascular diseases, but also include deteriorating health of liquidators; increasing invalidity among liquidators and decreased birth rate.

Very little is known concerning the community, ecosystem or evolutionary effects of broad scale chronic exposure to radioactive contaminants in non-human systems. Most studies in the past have focused on characterizing the transfer of contaminants (i.e. received dose), morphological correlates (e.g. asymmetry), or genetic consequences of contaminants, which are valuable and necessary prerequisites for further research. Recent studies of natural populations suggest that there are significant reproductive and population level effects in some species that could influence community (i.e. biodiversity) and ecosystem (i.e. energy flow) dynamics. Dr. Timothy A. Mousseau (University of

South Carolina) has presented data on chronic exposure to radionuclides in non-human species. In some of recent work he examines reproduction, survival, and other effects in natural populations of animals and will propose future directions for research in this area.

The mental health impact is perhaps the most serious public health problem unleashed by the accident to date. The magnitude and scope of the disaster, the size of the affected population, and the long-term sequelae make it, by far, the worst industrial disaster on record. Chernobyl accident caused a complex web of events and long-term difficulties, such as massive relocation, loss of economic stability, and long-term threats to health in current and possibly future generations, that resulted in an increased sense of anomie and diminished sense of physical and emotional balance. While it may never be possible to disentangle the multiple Chernobyl stressors from those that followed in its wake, including the dissolution of the Soviet Union, the high levels of anxiety and medically unexplained physical symptoms continue to the present. The studies also reveal the importance of eliminating reporting bias in epidemiological studies of health effects.

The main areas of concern after this disaster involve stress-related symptoms, effects on the developing brain, organic brain disorders in highly exposed clean-up workers, and suicide.

With respect to stress symptoms, increased levels of depression, anxiety (including post-traumatic stress symptoms), and medically unexplained physical symptoms have been found in Chernobyl-exposed populations. Compared to controls, three studies found that exposed populations had anxiety symptom levels that were twice as high and were 3-4 times more likely to report multiple unexplained physical symptoms and subjective poor health. Interestingly, in one study, 31% of the mothers of evacuee children reported that their child had memory problems compared to 7% of controls. This is consistent with possible reporting bias.

These mental health consequences in the general population were mostly sub-clinical and did not reach the level of criteria for a psychiatric disorder. Nevertheless these sub-clinical symptoms had important consequences for health behavior, specifically medical care utilization and adherence to safety advisories. To some extent, these symptoms were driven by the belief that their health was adversely affected by the disaster and the fact that they were diagnosed by a physician as a “Chernobyl-related health problem.” These studies point to the importance of eliminating reporting biases that may occur in other epidemiological studies of health status and potential radiation effect.

A great deal of concern has been expressed about the developing brain of children who were *in utero* when the accident occurred. On the one hand, the lowest level of exposure in which mental retardation was found in the offspring of survivors of Hiroshima and Nagasaki was higher than the highest level of exposure reported for most Chernobyl populations. Moreover, there is a general belief that the brains of Chernobyl exposed children may have been in some way damaged. Thus, the World Health Organization conducted the Pilot Project on Brain Damage *in-utero* under the auspices of the International Program on the Health Effects of the Chernobyl Accident (IPHECA). Analysis of the results in the three countries has shown the following:

- a) the prevalence of mild mental retardation in prenatally irradiated children is higher when compared with the control group;
- b) an upward trend was detected in cases of behavioral disorders and in changes in the emotional problems in children exposed *in utero*;
- c) the prevalence of borderline nervous and psychological disorders in the parents of prenatally irradiated children is higher than that of controls.

The IPHECA study had several crucial limitations, of which the most important was the impossibility of linking the results to individual doses. The definition of an exposed and unexposed child was based only on the contamination level of the soil of the district of residence, without reference to individual doses (World Health Organization 1995).

Two recent well-designed studies using standard batteries of neuropsychological tests failed to find systematic differences in children exposed *in utero*. However, no dosimetric data were available, and there were no normative data in Ukraine for the measures used in the study. Moreover, the IQ tests were applied selectively

On account of the contradictory results of the mental health assessments of the *in utero* exposed children and the etiology of the observed neuropsychiatric disorders in the literature, a thorough study of the potential radiation effects on the mental health of the *in utero* exposed children was performed within the framework of the Project 3 «Health Effects on the Chernobyl Accident» of the French-German Initiative for Chernobyl. The prenatally exposed children show significantly more neuropsychiatric disorders, lower full-scale IQ due to lower verbal IQ and therefore an increased frequency of performance/verbal intelligence discrepancies. When IQ discrepancies of the prenatally irradiated children exceeded 25 points, there appeared to be a correlation with the fetal dose (Nyagu et al., 2004a,b,c). Moreover, the neurophysiological markers of prenatal exposure were revealed. The most critical period of cerebrogenesis at the radiation accident on the nuclear reactor are the later terms of gestation (16–25 weeks) than that at uniform external exposure (Loganovskaja & Nechayev 2004; Loganovskaja, 2004, 2005).

Current evidence concerning mental health and brain effects following the Chernobyl accident is as follows:

- The preliminary results the Franco-German Chernobyl Initiative sub-project 3.8.1 «Data base on psychological disorders in the Ukrainian liquidators of the Chernobyl accident» testify a two-fold increase of the prevalence of any mental disorders and depression in liquidators in comparison with Ukrainian general population — 36% vs 20.5% and 24.5% vs 9.1% (Romanenko et al., 2004a,b; Demyttenaere et al., 2004).
- Evacuees have significantly more health problems and rate their health more poorly overall (Adams et al., 2002; Bromet et al., 2002).
- In the liquidators radiation risks on non-cancer effects has been revealed (Biriukov et al., 2001; Buzunov et al., 2001, 2003). The highest radiation was found for cerebrovascular diseases (Ivanov et al., 2000).
- Organic brain damage with inhibition of the cortical-limbic system was revealed in patients who had acute radiation sickness (ARS) and in liquidators of 1986 (Loganovsky & Yuryev, 2001). The neurophysiological markers of ionizing radiation (1–5 Gy) were found (Loganovsky & Yuryev, 2004).
- Dysfunction of sub cortical limbic-reticular and mediobasal brain structures and the white matter damage including corpus callosum in remote terms after exposure to radiation were observed (Zhavoronkova et al., 2000, 2003).
- Impairment of cognitive function, especially in liquidators, resulting from both acute and chronic exposure to ionizing radiation were revealed (Gamache et al., 2005). The neural diathesis-stressor hypothesis of schizophrenia is considered as a model of the effects of exposure to ionizing radiation (Loganovsky et al., 2004a, 2005a).

- The organic brain damage in remote period of ARS has been verified by clinical neuropsychiatric, neurophysiological, neuropsychological, and neuroimaging methods (Loganovsky et al., 2003; 2005b).
- There are the neuropsychological dose-effects relationships at 0.5–5 Sv dose range (Antipchuk, 2004, 2005).
- There is the «dose–effect» relationship between the dose and the characteristic morphometric neuroimaging features of organic brain damage, starting with 0.3 Sv and increasing in proportion to the dose (Bomko, 2004a).

The structural-functional pattern of radiation organic brain damage in Chernobyl accident clean-up workers consists in the pathology of cerebral cortex, subcortical structures, neuronal pathways and cortical-limbic system of the left (predominantly) cerebral hemisphere (Loganovsky & Bomko, 2004). Exposure to low-dose ionizing radiation could be a risk factor for accelerated aging processes and neurodegeneration. (Bazyka et al., 2004).

- At exposure lower than 0.3 Sv, Chronic Fatigue Syndrome (CFS) was diagnosed in 26% liquidators (Loganovsky, 2003). CFS and Metabolic Syndrome X (MSX) are considered to be the stages of another neuropsychiatric and physical pathology development, and CFS can transform towards MSX (Kovalenko & Loganovsky 2001). CFS can be considered as environmentally induced predisposition and vestige of forthcoming neurodegeneration, cognitive impairment, and neuropsychiatric disorders (Volovik et al., 2005).
- Further well-designed neuropsychiatric epidemiological studies in Chernobyl accident survivors have a priority, particularly concerning schizophrenia spectrum disorders, suicides, and CFS. Neuropsychiatric follow up survey of the ARS-patients has to be continued for a life time. In vivo morpho-functional (fMRI; qEEG, EP) and neurochemical studies (SPET) are of the greatest priority (Loganovsky et al., 2005b).

The accident has had a serious impact on mental health and well-being in the general population. Importantly, however, it appears that this impact is demonstrable mainly at a sub-clinical level. Although the empirical studies do not support the view that the public anxiety bears a resemblance to clinical psychiatric disorders, such as phobia or psychosis, the disaster did have a psychological effect that is not limited to mental health outcomes. It also has ramifications for other areas of subjective health and health-related behavior, especially reproductive health and medical service utilization. It furthermore may influence people's willingness to adopt safety guidelines issued by the authorities.

According to current knowledge, the evidence-based radiation cerebral effects could be outlined as follows:

- Non-cancer effects, especially cerebrovascular, at doses >0.5 Sv;
- Dose-related cognitive decline following radiotherapy in childhood with the possible dose thresholds of delayed radiation brain damage at the doses as low as 0.25–1.3 Gy on the brain;
- Dose-related cognitive and neurophysiological abnormalities in prenatally exposed children;
- Post-radiation organic brain syndrome in ARS-patients and dose-related neuropsychiatric, neurophysiological, neuropsychological, and neuroimaging abnormalities following exposure to >0.3 Sv.

The CNS effects that could be studied are as follows:

- Schizophrenia spectrum disorders;
- Chronic Fatigue Syndrome;
- Accelerated aging processes and neurodegeneration.

What the Chernobyl disaster has clearly demonstrated is the central role of information and how it is communicated in the aftermath of radiation or toxicological incidents. Nuclear activities even in Western countries have also tended to be shrouded by secrecy. The Chernobyl experience has raised the awareness among disaster planners and health authorities that the dissemination of timely and accurate information by trusted leaders is of the greatest importance.

## **MEDICAL LESSONS LEARNT FROM CHERNOBYL (Prof. D. Bazyka)**

Dr. Bazyka has made the presentation “Chornobyl accident as a model for health effects management after radiological attack”. Main goal has to be an integration and generalization of the Chornobyl accident experience by evaluating all the medical-biological and dosimetric registers and databases available in Ukraine, for the elaboration of a strategy for the operational health effects management of the most vulnerable groups of population and its specific pathologies and target organs and for decision making for interventions after radiological attacks. Information will be gained on the health state of population depending on the use of radioprotectors. This will be of special interest for stable iodine, data on which are controversial (DHS working group, 2003). Specific aims are as follows:

- Generalization of epidemiological analysis and risk assessment of health effects of the Chornobyl accident;
- Retrospective assessment of medical countermeasures and social protection efficacy for different categories of the Chornobyl accident victims and affected population (including also evacuation criteria, psychological support, contamination analysis/mapping, water/food decontamination and supply, radionuclide transfer via nutrition chains, etc.);
- Lessons and mistakes to be learned from the Chornobyl accident experience analysis; Retrospective assessment of efficacy of the protectors decreasing or blocking of internal exposure to radioiodine, cesium-137 and strontium-90 at the early stage after Chornobyl accident (stable iodine, Prussian blue, biological response modifiers); Improvement of the guidelines for decision making on medical countermeasures and intervention levels after radiological accidents:
  - i) Establishing protective action guidelines for A-team;*
  - ii) Making evacuation and relocation decisions for A-team;*
  - iii) Evaluating health and medical impact on the public and emergency personnel*
  - iv) Communicating with the public, policy makers, and the media*

The significance of such study is a development of effective medical countermeasures against radiation for clinical use following radiation accident at nuclear reactor: guidelines for decision making on medical countermeasures and interventions after radiological accidents;

- Recommendations on the use of stable iodine;
- Regimens that mitigate and/or treat radiation injury post-exposure, with emphasis on broad activity, ease of administration, and safety;
- Low-dose radiation effects and prevention of long-term disease, such as fibrosis, organ dysfunction, and cancer; including models of accelerated disease that will facilitate research;
- Mechanisms of radiation protection, injury, or repair in the hematological, gastrointestinal, pulmonary, renal, cardiovascular, and central nervous systems, as well as the skin, soft tissue, and liver. Such could be based on the comprehensive epidemiological analysis of health effects of the Chornobyl accident on the base of the all available in Ukraine registers with their quality control.

## **DOSIMETRY AND DOSE RECONSTRUCTION (Dr. Miller, US CDC)**

During a radiological post-emergency response, public health officials will be required to advise members of the public on the possible health consequences resulting from their exposure to radionuclides. Providing this advice will require knowledge of the radiological doses received by persons during the event. Such doses will likely need to be reconstructed from environmental and other types of measurements made during the emergency event. The Centers for Disease Control and Prevention is currently conducting environmental dose reconstructions at many nuclear weapons production and testing sites in the United States. These projects involve reconstructing potential radiation exposures and doses from past releases of radionuclides to people who lived near nuclear facilities where these releases occurred. The results of dose reconstructions can be used as the basis for deciding if epidemiologic studies or other public health activities should be undertaken around these sites. In addition, the results of dose reconstruction can be used in other site-specific risk assessment activities, such as those associated with environmental restoration and radioactive waste management. All of the environmental dosimetry methods developed for dose reconstruction purposes are potentially applicable to post-emergency response environmental risk assessments, too. The most important application of CDC's experience, however, may be in the area of public involvement. CDC has learned that the success of any dose reconstruction depends as much on public involvement in the project as on the scientific and technical credibility of the methods used to estimate doses and exposures. The future activity in this field will include the assessment of individual doses, necessary for more precise evaluations, the reconstruction of doses of exposed individuals, the quality revision of existing data.

### **SOME PRELIMINARY CONCLUSIONS**

- The updated epidemiological result indicates that the risks caused by the Chernobyl accident include more than thyroid cancer. Leukemia and women breast cancer should be considered in this framework, even if more study is necessary. Moreover, other cancer categories (colon, lung, and bladder) should be also taken into account.
- Whole body irradiation, even at not very high doses, may represent a risk factor for ischemic heart diseases, cardiomyopathy, cerebrovascular diseases. The estimated risk for cardiovascular diseases is higher than but compatible with, the one observed in the Atomic Bomb Survivors (ABS).
- Neurological and cerebrovascular diseases increases have been detected.
- Psychological and social effects are clearly evident, including depression, impact on mental health and well-being, anxiety, decisions of reducing births, some suicide increase, and other effects.
- The cause of psychological disorders is not only attributable to a lack of an appropriate risk communication. Population relocation, loss of home and lifestyle, loss of work, poverty and other related conditions evidently are important factors.
- Moreover, taking into account the high risk perception by the involved people, it seems important to adopt an appropriate form for the diffusion of risk estimates. For instance, the recently diffused information, that about 3,900 radiation-induced deaths from thyroid cancer or leukemia are expected, may evidently have a serious psychological impact on the involved people. Provided that the involved population is of around 600,000 people, the same information might be also expressed in terms of a radiation-induced mortality risk of about 6 cases per 1000, which corresponds to a

very low fraction of the independently existing background risk. Some experience in risk communication suggests that this latter form (avoiding the crude indication of the number of expected deaths) has a much lower negative effect on the risk perception of involved subjects.

- The history of the emergency response to the accident is particularly interesting and allows the identification of problems possibly arising in the practical management of the event consequences. The lessons learned in this field are very important, because, generally, they are scarcely addressed in the scientific literature. The above summarized points are only a limited part of the information available from the personnel that was directly involved.
- The above mentioned evaluations in the IARC and Prof. Bazyka presentations, concerning the efficiency in thyroid cancer risk reduction of iodine administration to people at risk and of the normal iodine dietary intake of the same people, are important for the evaluation of possible residual risks that presumably may not be excluded at all.
- The uneven distribution of environmental contamination and of population exposure implies a difficulty in detecting possible effects in most exposed sub-groups, whenever their “critical conditions” are not separately and specifically considered. The importance of epidemiological analytic studies is confirmed by recent results.
- The recently published study “Risk of cancer after low doses of ionizing radiation: retrospective cohort study”, coordinated by the IARC (Cardis et al., 2005), that indicates a significant cancer risk at very low doses (even at the level of the current occupational exposure limit and also below it) is of importance for the Pilot Study here discussed.
- The efficiency of iodide treatment for thyroid cancer prevention should be re-evaluated, together with the possible residual risk.
- Finally, an important information, in terms of lessons learned, is represented by the positive impact, in terms of risk reduction, of the countermeasures adopted (e.g., the Prypyat town evacuation in a low number of hours, etc.). These aspects are under study. However, it may be reasonably assumed that if the Chernobyl accident consequences were not so high as initially predicted, this is also due to the emergency response. It is worthwhile remembering that many people have lost their lives for this purpose.

From a more practical point of view:

- The need of an extremely rapid monitoring and/or assessment of contamination and exposure levels in territories possibly very large, together with updated criteria and emergency plans for decision making in the emergency action.
- The need of providing adequate uncontaminated food resources to populations resident in contaminated areas, for preventing the alimentary use of local agricultural and animal products and the related internal exposure.
- The need of an extremely rapid distribution system of prophylaxis resources and radio-protective drugs to the population groups at risk.
- The need of a prior adequate planning of evacuation procedures, including the transport systems, the appropriate identification of the areas and buildings for population relocation, a medical, psychological and social support to the evacuated people.