SUMMARY REPORT
of the CCMS Pilot Study meeting held in Kiev, June 10th – 12th, 2004 on the "Risk assessment of Chernobyl accident consequences: Lessons learned for the future"

Background: The Pilot Study represents the continuation of a collaborative scientific activity started on April 8th-12th, 2003, with the international workshop: "Risk assessment of Chernobyl accident consequences", held in Kiev, Ukraine with 37 participants from Ukraine, Belarus, Russian Federation and Lithuania and 14 participants from western Europe and USA attended to the workshop (Austria, Germany, Greece, Italy, Portugal, Spain, US), respectively presenting 29 and 10 papers.
Preparatory meeting was conducted in Rome. The Scope of Preparatory Meeting was the discussion of the Pilot Study program. preliminary collection of synthetic data, evaluations, assessments on the above listed points, provided by participants, in order to produce a first document to be submitted to a larger meeting and organization of the first extended Pilot Study meeting to be held in 2004 in Eastern Europe, presumably in Kiev.

The context of the CCMS Pilot Study meeting:

This meeting makes part of the CCMS Pilot study "Risk Assessment of Chernobyl Accident Consequences: Lessons Learned for the Future" (Co-Directors - Dr. G.A. Zapponi, Italy and Dr. C.C. Travis, United States).

The Chernobyl accident triggered a considerable improvement of national and international procedures for nuclear emergency management and preparedness, especially in the areas of international communication and information exchange. However, there still remains room for improvement, for example in the field of coordinating the response to nuclear accidents, as well as in the area of decision making in the initial and later phases after an accident.

The purpose of this study group is to focus on lessons learned from the Chernobyl accident. In order to extract lessons learned, we must first review the current state of knowledge regarding the Chernobyl accident. This information is to be transformed into recommendations for further research and for improving decision making while responding to future accidents.

The CCMS Pilot Study Meeting structure

Six basic topics have been discussed:
- Dosimetry
- Effects on Children
- Other carcinogenic effects
- Non-Cancer Endpoints
- Psychological Effects
- Integration of the above items and Lessons for future.

For each of the five first items, the working groups were defined. The available relevant documentation was distributed in advance to participants. Working groups included both experts who have dealt with the management of the accident consequences and their evaluation, and experts of risk assessment procedures.

SUMMARY ON THE MAIN WORKSHOP TOPICS

Dosimetry

The Chernobyl accident resulted in widespread radioactive contamination on the territories of Belarus, Russia and Ukraine. The main radionuclides were ^{137}Cs and ^{131}I. We will review current knowledge of the doses received by populations in the affected countries. Particular attention will be also given to the most critical exposure patterns, that may be assumed to be responsible of the most serious health effects, with the purpose of obtaining information suitable for effective prevention strategies in similar conditions.

The recovery operation workers were mainly exposed to external irradiation arising from the contamination of the site by radioactive materials. The workers exposed involved in various manners accident can be divided into two main groups: (a) the emergency workers, who were involved in fire fighting and other emergency measures during the first day of the accident (26 April 1986), and (b) the recovery operation workers, who were active in 1986-1990 at the power station or in the zone surrounding it for decontamination work, sarcophagus construction, other recovery operation activities, and the operation of other units of the nuclear power plant.

As far as the recovery operation workers are concerned, estimates of doses from external gamma irradiation could be obtained either at the time of exposure or retrospectively. At the time of exposure, three methods were used: (a) individual dosimetry for atomic energy workers and a small part of the military personnel after June 1986; (b) group dosimetry (an individual dosimeter was assigned to one member of a group of recovery operation workers performing a particular task, and all members of the group were assumed to receive the same dose); and (c) group assessment method (dose to the whole group of liquidators was assessed by a dosimetrist in advance with respect to the dose rate at work location and planned duration of work). Methods of retrospective dose estimation include: (d) time-and-motion studies (measurements of gamma-radiation levels were made at various points of the reactor site, and an individual's dose was estimated as a function of the points where he or she worked and the time spent in these places), and (e) biodosimetry (Electron Paramagnetic Resonance (EPR) measurements on teeth, or Fluorescence In-Situ Hybridization (FISH) measurements on blood lymphocytes. Methods (b) and (c), or their combination, were used for the majority of the military personnel at all times. So far, method (e) has only been used for validation purposes on a limited number of workers.

The main sources of uncertainty associated with the different methods of dose estimation are as follows:

- individual dosimetry (method a): incorrect use of the dosimeters (inadvertent or deliberate actions leading to either an overexposure or an underexposure of the dosimeters);
- group dosimetry (methods b and c) : very high gradient of exposure rate at the working places at the reactor site;
- time-and-motion studies (method d): deficiencies in data on itineraries and time spent at the various working places, combined with uncertainties in the exposure rates. A high degree of conservatism was used in the early applications of the method;
- biodosimetry (method e): a relatively high background that prevents the low doses to be measured with reliability and a lack of knowledge on the other sources of radiation exposure.

Uncertainties associated with the different methods of dose estimation have been assessed to be up to 50% for the method (a) (if the dosimeter was correctly used), up to a factor of 3 for method (b), and up to a factor of 5 for methods (c) and (d) (Pitkevitch et al. 1997).

The internal doses resulting from intakes of radionuclides such as ^{90}Sr, ^{137}Cs, ^{239}Pu and others, have been assessed for about 300 recovery operation workers who were monitored from June to September 1986. The majority of them were staff of the power plant who took part in the recovery work starting on days 3 and 4 after the accident. They were selected on the basis of their high levels

of external exposure. The dose assessment was based on the analysis of whole-body measurements and of radionuclide concentrations in excreta. The average value of the effective dose committed by the radionuclide intakes was estimated on the basis of ICRP Publication 30 to be 85 mSv. [VK to provide comparison with external doses for the same workers]

The national registry data for Belarus, Russia, and Ukraine, presented in Table D-1, show that the number of recovery operation workers and the average recorded doses (from external irradiation only) decreased from year to year, with a mean dose of about 130 mGy in 1986. The decrease in recorded doses reflect the decrease in the dose limits, which, for most workers, were 250 mGy in 1986, 100 mGy in 1987, and 50 mGy in 1988 and in later years. The percentage of recovery operation workers with recorded dose follows the reverse tendency: it is low in 1986 and 1987, when the doses are relatively high, and it is higher in 1988-1989, when the doses are lower. Although the doses presented in Table D-1 provide an indication of the exposures, they are not to be relied upon without further analysis because of the biases introduced by some of the methods of dose estimation and the falsification of data that occurred for a small percentage of workers.

For analytic epidemiological studies, the dosimetric information that is requested is an estimate of the absorbed dose of interest (bone marrow for blood diseases, breast for breast cancer, etc.) for all individuals enrolled in the study, as well as an assessment of the uncertainty attached to the dose estimate. For that purpose, the registry data need to be supplemented with other information, including some obtained during personal interviews. On-going epidemiological studies use a time-and-motion method, called RADRUE. Results of RADRUE implementation were discussed on the basis of Leukemia in clean-up workers study in Ukraine. This method relies on an accurate knowledge of the radiation field at the locations where the worker was exposed, as well as the whereabouts of the worker, which are obtained by means of personal interviews. Biodosimetry methods are also used to validate the dosimetry results recorded in the Registries or obtained with RADRUE.

Table D-1. Distribution of external doses to recovery operation workers as recorded in national registries [Add similar information from the Baltic countries?] (refs: Kenigsberg 2004; MH 1999; Cardis et al. 1996).

Country and period	Number of recovery operation workers	Percentage for whom dose is known	External dose[a] (mGy)			
			Mean	Median	75th percentile	95th percentile
Belarus						
1986	68 000	8	60	53		
1987	17 000	12	28	19		
1988	4 000	20	20	11		
1989	2 000	16	20	15		
1986-1989	91 000	9	46	25		
Russian Federation						
1986	69 000	51	169	194	220	250
1987	53 000	71	92	92	100	208
1988	20 500	83	34	26	45	94
1989	6 000	73	32	30	48	52
1986-1989	148 000	63	107	92	180	240

Ukraine	98 000	41	185	190	237	326
1986	43 000	72	112	105	142	236
1987	18 000	79	47	33	50	134
1988	11 000	86	35	28	42	107
1989	170 000	56	126	112	192	293
1986-1989						

[a] The external dose is expressed in mGy for reasons of convenience. In fact, the quantity measured was, in many cases, exposure.

The Registry data are incomplete, as they cover less than half of the total number of recovery operation workers, and do not include information on affiliation or on the type of work carried out on the site.The Registry data need to be supplemented using other information and verified using another method. Absorbed doses for the organ or tissue of interest in the epidemiological studies are not available in the literature. They remain to be calculated on the basis of limited information on the radiation fields in various locations and various times after the accident.
Doses from internal irradiation are expected to have been small, when compared to the doses from external irradiation, but they have not been given much attention. Information on doses from beta radiation to the skin and to the lens of the eye also is limited.

There are large uncertainties in the dose estimates obtained by means of the various methods and it is not clear whether these uncertainties could be reduced substantially. In particular, the influence of the recall bias during interviews has not been studied adequately.
Biodosimetry methods (EPR and FISH) have been applied to a limited number of workers, but their application is limited to relatively high doses (50 mGy for EPR and 300 mGy for FISH).
The doses received by the members of the general public resulted from the radionuclide releases from the damaged reactor, which led to the ground contamination of large areas. Iodine-131 was the main contributor to the thyroid doses, received mainly via internal irradiation within a few weeks after the accident, while ^{137}Cs was, and is, the main contributor to the doses to organs and tissues other than the thyroid, from either internal or external irradiation, which will continue to be received, at low dose rates, during several decades.

Within a few weeks after the accident, more than 100,000 persons were evacuated from the most contaminated areas of Ukraine and of Belarus. The thyroid doses received by the evacuees varied according to their age, place of residence, and date of evacuation. For example, for the residents of Pripyat, who were evacuated essentially within 48 h after the accident, the population-weighted average thyroid dose is estimated to be 0.17 Gy, and to range from 0.07 Gy for adults to 2 Gy for infants. For the entire population of evacuees, the population-weighted average thyroid dose is estimated to be 0.47 Gy. Doses to organs and tissues other than the thyroid were, on average, much smaller (Table D-2).
Table D-2. Summary of estimated thyroid and effective doses to populations of areas evacuated in 1986 (Bennett et al. 2000).

Country	Estimated arithmetic mean dose		
	Thyroid (Gy)	External effective (excluding thyroid dose) (Sv)	Internal effective (excluding thyroid dose) (Sv)
Belarus	1.0	0.03	0.006

Ukraine	0.3	0.02	0.01

Doses also have been estimated for the approximately 6 million residents of the contaminated areas (defined as being areas where the ^{137}Cs deposition density was greater than 37 kBq m^{-2}) who were not evacuated. Following the first few weeks after the accident when ^{131}I was the main contributor to the radiation exposures, doses were delivered at much lower dose rates by radionuclides with much longer half-lives. Since 1987, the doses received by the populations from the contaminated areas have resulted essentially from external exposure from ^{134}Cs and ^{137}Cs deposited on the ground and internal exposure due to contamination of foodstuffs by ^{134}Cs and ^{137}Cs. Other, usually minor, contributions to the long-term radiation exposures include the consumption of foodstuffs contaminated with ^{90}Sr and the inhalation of aerosols containing ^{239}Pu. Both external irradiation and internal irradiation due to ^{134}Cs and ^{137}Cs result in relatively uniform doses in all organs and tissues of the body.

Methodologies of dose estimation have been prepared in Belarus, Russia, and Ukraine and applied to the populations of the contaminated areas. Catalogs of average doses in all settlements of the 3 Republics are available (refs?). The average effective doses from ^{134}Cs and ^{137}Cs that were received during the first ten years after the accident by the residents of contaminated areas are estimated to be about 0.01 Sv (Table D-3).

Table D-3. Summary of estimated average effective doses (excluding thyroid doses) to populations of areas contaminated by the Chernobyl accident (1986-1995)[a] (Bennett et al. 2000).

Country	Estimated arithmetic mean effective dose (mSv)		
	External exposure	Internal exposure	Total
Belarus	5	3	8
Russian Federation	4	2.5	6.5
Ukraine	5	6	11

The dosimetric information needed in analytic epidemiological studies consists of individual absorbed doses in the tissue of interest for all subjects, as well as estimates of uncertainty. The method currently used to derive the individual dose estimates consists in modifying the average doses provided in the catalogs, using information obtained by means of personal interviews. For external irradiation, the information necessary is the residence history, together with the type of building where the subject worked and resided. For internal irradiation, information on foodstuffs (type, origin, and consumption rates) is needed. In order to estimate or reduce the uncertainties in the individual doses, validation studies have been conducted (refs?) using personal dosimeters for external irradiation and data on whole-body contents or radionuclide concentrations in foodstuffs (usually milk) for internal irradiation.

Computational methods of retrospective and prognosis assessment need in further developments and verification on base of direct measurings. "Chernobyl" dose formation for population depends on properties of radionuclide migration in natural environments and on capacities of radionuclide's ways of entrance to human organism. Therefore dose specification is a common problem of radioecologists and dosimeterists. Dr. Grodzinsky and Dr.Kravets have proposed model (EMARC) need adaptation for regions not only different natural but social conditions. The development of most adequate computational method would allow not only to forecast the consequences of the Chornobyl's accident, but also will form the principle basis for ecological and medical forecasting of any man-caused pollution. Population of polluted territories live in condition permanent

irradiation with low rate dose. In parallel with dynamic of epidemiological picture investigation it is need investigated cumulative effects in generations of different experimental shot -lived objects in condition of protracted exposure. These data need for forecast dynamic of stochastic and nonstochastic effects for man.

Methodologies for the estimation of the effective doses in any settlement of the contaminated areas of Belarus, Russia, and Ukraine have been developed and applied to the populations of those settlements.

Catalogs of effective doses are available, both for annual doses and for doses accumulated until 1995, 2001, or 2002.Validation studies have been conducted, both for external and for internal irradiation. Still some issues are not solved i.e.

Intercomparison of methods (currently in progress).

Reliability of interviews.

Estimation of doses received in utero.

Conversion from effective doses to absorbed doses in the organ or tissue of interest (red bone marrow, lung, stomach, kidney, etc.).

Lessons for future

- The RADRUE method, which is applied in the on-going epidemiological studies, should continue to be validated using reliable results obtained by means of other methods. Efforts to quantify and/or to reduce the uncertainties associated with the RADRUE method should be pursued.
- Biodosimetry methods should be used to validate the RADRUE method. However, efforts should be made to make sure that they can be applied reliably to all workers above a certain dose level.

For dose estimation in general public efforts should be made or continued to:

- intercompare the methods of dose estimation;
- assess the reliability of the interviews;
- estimate the doses received in utero; and
- derived absorbed doses from the effective doses available in the catalogs.

Effects on Children

The Chernobyl accident resulted in a significant increase in the number of thyroid cancers in children. Thyroid cancers were most prevalent in children aged 0 to 5 years at the time of the accident, and in areas assessed to be the more heavily contaminated with 131I. We will review the current knowledge on this issue.

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 elaborated of children irradiated in utero in Prypjiat. Neuropsychological 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 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.

Prognosis of the health of the exposed children remains unfavorable for a long time in the post-accidental period.

Screening studies of children from contaminated territories of Kiev and Zhitomir regions including those evacuated from Pripyat with the help of questionnaires have demonstrated significant increase

of number of children in the risk groups. Medical, genetic, predisposition, social and microsocial, economical, environmental factors were encountered. Factors that could contribute to the formation in future of a thyroid pathology are shown in 32,6% of children (control group – 15,4%), respiratory diseases - 26,0% at exposed (in control group – 13,7%), cardiovascular diseases (including vegetative dysfunctions)- 57,8% (control group – 31,8%), digestive tract diseases– 18,9% (control group – 8,9%), immune deficiency – 43,5% (control group – 28,0%), reproductive sterility (among girls) – 32,0% (in control group – 10,5%.

Morbidity among children suffered during all post-accidental period is below or on the level of general morbidity value of children in the age from 0 to 14 years in Ukraine. Number of healthy children is decreasing progressively with increase of radioiodine dose absorbed by thyroid.

Nowadays by non-tumor diseases in a population of survivors the following international studies are implemented.

- Incidence and mortality among children on contaminated territories (descriptively) – since 1993.
- Brain damage in utero (descriptively) – since 1993.
- Diets – since 1999.

Prospective directions for future studies could be considered:

- Incidence and mortality from cardiovascular pathology among evacuees;
- Thyroid irradiation and somatic pathology;
- Stress and public information;
- Molecular and biological studies and establishment of tissue banks.

Other carcinogenic effects

The existing epidemiological studies and evaluations relative to cancer effects, other than children thyroid cancer, have provided not fully consistent results. It seems important to further investigate these aspects, in order to carry out a comprehensive carcinogenic risk evaluation, also considering the still existing uncertainties. The information on the effects identified in other radiation exposed populations could also provide an appropriate framework for this task.

Chernobyl accident in 1986 led to exposure 4 millions of population in the Ukraine by ionising radiation. Some of them will received substantial dose of permanent radiation. This circumstance leads to necessity of study of stochastic cancer aftereffects in this group of population. To investigate relationship between Chernobyl radionuclide deposition and risk of development of solid cancer in population still living in most contaminated areas of Kiev and Zhytomir regions there was studied incidence and time trends of this pathology in 274,800 inhabitants of most contaminated areas at the moment of accident.

According to subject of the study there were collected medical documents on 10,764 cases of solid cancer. Demographical data about age and sex distribution in 1980-1999 allow to calculate age-specific and age-adjusted incidence rates. These data were compared with relevant national data.

Solid cancer incidence rate in studied areas in 1980-1999 is characterised by smooth evolutory increase. Time trends did not differ in pre- and post-accidental periods. Values of incidence rate in all period of time were lower than in the Ukraine.

Some forms of solid cancer show quite different trends. First of all this is thyroid cancer. After four or five years of latency there was observed quite remarkable increase of this malignancy, especially in children and juvenile age groups. Evaluation of this increase led to conclusion of consequences of irradiation of thyroid gland with radioactive iodine.

Close attention should be drawn to female breast cancer. After 6 or 7 years of stable level of breast cancer incidence rate there was observed steep increase since 1992. This form of cancer belongs to radiosensitive forms of malignancy and close attention should be attached in future.

Considering, that separate forms of malignancies have different latency period of occurring after radiation exposure, it is important to continue long-term epidemiology studies on this subject.

To estimate relationship between Chernobyl radioiodine deposition and risk of development of thyroid cancer in adolescents and adults there were studied integrated deposition of ^{131}I in heavily contaminated regions of the Ukraine (Chernigov, Kiev, Zhytomir oblasts) at the rayon level and thyroid cancere incidence rate in 1980-1999 in population 15 years and older. Total size of population of three regions is 4,7 mln.

There are 24 rayons with average level of integrated ^{131}I deposition of 50 kBq m^{-2} (GR 1). In group of average level of integrated ^{131}I deposition - 136 kBq m^{-2} (GR 2) there are 29 rayons. In the most contaminated group of rayons (GR 3) with average 513 kBq m^{-2} ^{131}I deposition there are 18 rayons.

There was collected an information about 2908 thyroid cancer cases in adolescents and adults (15+) and population at studied territory in 1980-1999. Descriptive and analytical epidemiological study of thyroid cancer incidence rate in total and separate oblasts and periods of time has been performed. Comparison of time periods 1980-1990 and 1991-1999 revealed a significant increase of thyroid cancer incidence rate. This increase occurred due to the increase in all age groups. Pooled data suggest steady increase of thyroid cancer incidence rate in males from 0.48 per 100,000 in 1980 to 3.70 per 100,000 in 1999 and in females from 1.34 per 100,000 in 1980 to 11.48 per 100,000 in 1999.

The fitting of the data on truncated age-standardized thyroid cancer incidence rates (TASR) in 1980-1990 was obtained with the model of linear increased rates for females and constant rates for males. The parameters of these models estimated were used to calculate the "expected" (background with screening) rates for females and males in 1991-1999. The excess rates with its uncertainties were estimated as rate difference between "observed" and "expected" rates for period of 1991-1999.

The existence of reliable excess, radiation caused, component in the thyroid cancer incidence rate is first detected in adolescents and adults of three Ukrainian oblasts in the post-Chernobyl period. The ratios of "observed" to "expected" TASR, stadrardised rate ratios (SRR), in combined group of adolescents and adults (15+ years at diagnosis) increase from 1.77 in 1991-1995 up to 3.03 in 1996-1999 for males and from 1.18 up to 1.55 for females in corresponding periods. In other words, the effect of exposure has a tendency to growth with time.

Analysis of TASR in the groups of the rayons (GRs) with different levels of ^{131}I integrated deposition proved the excess thyroid cancer rates in adolescents and adults in the rayons most contaminated with radioiodine. The ratio of TASR for 1991-1999 in age group of adolescents and adults combined (15+ at diagnosis) in the heavy contaminated GR #3 to low contaminated GR #1 (SRR_{31}) was 1.67 [1.25, 2.23] for males and 2.59 [2.22, 3.03] for females. Similarly, the ratios of rates in GR #2 (medium contaminated) to GR #1 (SRR_{21}) were statistically significant. No significant difference was detected between GRs #2 and #3.

The approximate estimate was made for the number of excess, radiation induced, thyroid cancer cases in adolescents and adults in three Ukrainian oblasts during 1991-1999: 184 excess cases in males and 442 excess cases in females.

Non-Cancer Endpoints

A number of radiation related non-cancer endpoints are of concern following the Chernobyl accident. It is anticipated that information on the development of cataracts in clean-up workers and others who may have received significant exposures will soon be available as well. There are 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; decreased birth rate.

During about 20 years the selective cytogenetic monitoring among the critical groups of Chernobyl accident victims in Ukraine have been fulfilled. Conventional, G-banding and since 1997 molecular (FISH-WCP) cytogenetic methods have been used for the examination of the high priority groups. In the delayed terms following the accident in all exposed groups (patients recovered from acute radiation sickness - ARS, clean-up workers mainly 1986, Chernobyl power plant personnel, persons evacuated from Pripyat, self-settlers from 30-km alienation zone, children and adults from regions of obligatory and voluntary evacuation) the frequency of chromosome aberrations (as integral as specific for radiation exposure) significantly elevated the pre-accident parameters typical for the spontaneous chromosome mutagenesis in peripheral blood lymphocytes. The increased number of radioinduced cytogenetic markers (mainly stable) have been discovered in some exposed groups (patients recovered from ARS, liquidators with stable lymphopenia, personnel of Sarkophagus, children evacuated from Pripyat, persons living and/or working in contaminated by radionuclides territories) even with the help of conventional and G-banding cytogenetics. Introduction of modern FISH technique essentially improved the possibilities of cytogenetic monitoring in terms of the discovery of stable chromosome aberrations (including clones), although under as traditional as molecular cytogenetics a wide interindividual variability of cytogenetic effects for the identical radiation exposure had been revealed. Comparison of the results of the conventional and fluorescence chromosome analysis showed that the discovery of translocations under the conventional staining with group kariotyping consisted no more than 29 % from the level of FISH translocations per whole genome. These data have been confirmed by the results of G-banding analysis. The calculation of the biological doses on the frequency of reciprocal translocations in comparison with the official dose records and results of EPR (tooth enamel) dosimetry showed that FISH technique can be used for retrospective group dosimetry under the doses above 25 cGy and for the individual dosimetry in dose range ~ 25 - 300 cGy (in view of aging factor).

Immune response parameters were studied in Chernobyl radiation emergency workers exposed to low-dose irradiation during 1986-1989 and nuclear industry workers exposed under professional limits. Analysis was performed in irradiation dose limits of 250 and 100 mSv. Comparison group included participants of the clinical-epidemiological registry (n-42,000) studied at the same time periods.

Initial response stage to the radiation exposure was characterized by immunological deficiency with T-cell subsets changes. Lymphocyte membrane changes and increased lipid peroxidation were demonstrated due to the free radical formation as well as elevated neutrophil peroxidase and catalase activities.

In the reconstitution period inhibition of immune function was associated with lymphocyte subset changes such as decreased CD3+ and CD4+ cells counts and increased number of somatic mutations in TCR-locus. Changes of the antioxidant defence enzymes, cholesterol content increase and the activation of the processes of lipid peroxidation were also characteristic for this period.

Late period after the acute radiation exposure in Chernobyl radiation emergency workers is characterized by decreased CD8+ supressor cell function that could lead to poor proliferation control. Radiation-exposed over 0.5Gy also are the risk group for leukemia development that is characterized by unlimited clonal proliferation. Role of association of elevated content of the metabolite of arachidonic acid 12-HETE as well as other eicosanoids (5-HETE, 15-HETE) produced by the activated platelets, low T-supressors and NK-cell counts in the promotion of malignant proliferation reactions have to be estimated with the comparative analysis of oncogene expression and the role of apoptosis. None of dependencies of dose-effect type were detected in nuclear industry workers. Different type of interdependencies between the immune function and

arachidonic acid metabolite 12-HETE is shown with the threshold values of 0.25-0.3 Gy. Lymphocyte reactions are supposed to be of adaptive origin.

The monohydroxylated fatty acid content of peripheral blood mononuclear cells from 23 clean-up workers and 16 unexposed people was studied in relation to their immune status at the remote period after Chernobyl accident. Patients with absorbed doses below 0.32 Gy showed higher levels of free and esterified 12-hydroxyeicosatetraenoic acid (12-HETE) than unexposed people whereas 15-HETE and the 17-hydroxy derivative of C22 fatty acid (17-OH 22) either free or esterified in phospholipids were dose-dependently increased. The percentage of CD4 positive cells was also significantly increased in heavily irradiated people, whereas those of CD8 positive cells tended to dose-dependently decrease. Furthermore, the absolute count of CD4 positive cells was positively correlated to the amount of 15-HETE esterified in the phospholipid fraction of mononuclear cells and to total 15-HETE level. The present study shows for the first time that the accumulation of autoxidized/lipoxygenase products of polyunsaturated fatty acids in the mononuclear cells of irradiated people was associated with immune imbalance. This may form the background for the remote effects of irradiation such as autoimmune disorders, somatic and oncologic diseases and early aging.

Considerable progress was done in studies of somatic effects after Chernobyl. During 1988-2003 complex clinical-morphological investigation of special features of COPD in 2113 liquidators of Chernobyl nuclear power plant accident and 309 persons of nosological control group was carried out. The doses of external exposure were found in interval from 2 to 76 cSv. Complex of contemporary research methods (clinical, peak flow-volumemetry, bronchofibers?opy, laboratory, morphological, immunological, microbiological etc.) was used. The inhalation influence of radionuclides on the bronchopulmonary system are taken into account too. All patients have not bronchopulmonary pathology before 1986 year. Above this, the group that contains 82 reconvalescents of acute light syndrome was investigated. Complex of contemporary research methods (clinical, peak flow-volumemetry, bronchofiberscopy, laboratory, morphological, immunological, microbiological etc.) was used. Argued, that treatment and clinical examination of liquidators and determination of expert questions had to take into account a presence of radiation induced pathomorphosys of COPD in this cohort of patients. The results of endoscopic examination of esophagus, stomach and duodenum were testified in 1735 Chornobyl NPP accident victims. In 47,8% of case have found duodeno-gastric and in 26,1% of case – reflux-esophagitis have found within the nearest period (1-1,5 years) after irradiation, intact mucosa was detected in 19 % of case. In 1990 the intact mucosa was revealed in 4,2 % of case, ulcer stomach and duodenum – 22,5%. The morphologic investigations of mucosa biopsy of different part of stomach allowed to reveal abnormalities typical for the certain forms of chronic gastritis

A number of factors inherent to the Chernobyl accident, including worsening socio-economic conditions, continuing residence in contaminated territories, diminished food supply, vitamin deficiency, relocation, and psychological stress, may contribute to these effects.

Psychological Effects

A number of non-radiation related health effects have appeared in affected populations as a result of the social, cultural and psychological stress caused by the accident the Chernobyl accident.

According to the opinion by the experts of the UNSCEAR-2000 (Annex J), mental health of the Chernobyl accident victims (all categories) is deteriorated due to psycho-social consequences only. There are psychological disorders, stress and anxiety due to the long-term changes in the lives of people as resettlement, changes in food supplies, restriction on the activities as well as economic, social, and political changes.

At the meeting there was presented the report on *social and psychological risks* of inhabitants of the radioactively contaminated areas (Prilipko et al.). Social and psychological stress on contaminated areas is still present. The core risk factors are as follows: radiation perception as the main stress factor; social risk factors; social and economic situation. They are realized in social and psychological disadaptation of population manifested as inactive behavior model, chronic distress, somatization, anxiety, and depression.

At the same time, epidemiological studies of the atomic bomb survivors have suggested dose-related increases in mortality from diseases other than cancer. Cardiovascular disease is one such non-cancer disease for which increases in both mortality and incidence have been found to be associated with radiation dose. (Kusunoki et al., 1999). The recognition in the atomic-bomb survivors of non-cancer effects at doses on the order of 0.5 Sv (half the dose level considered a threshold in earlier studies) should stimulate interest in deterministic effects (Shimuzu et al., 1999; Fry, 2001; Preston et al., 2003) and non-cancer morbidity and mortality following the Chernobyl accident.

In the Chernobyl accident clean-up workers (liquidators) radiation risks on non-cancer effects has been revealed (Biriukov et al., 2000; Buzunov et al, 2001, 2004). For some classes of non-cancer diseases among liquidators, statistically significant estimates of radiation risk were derived for the first time: mental disorders — ERR 1/Gy=0.4 (0.17; 0.64); neurologic and sensory disorders — ERR 1/Gy=0.35 (0.19; 0.52); endocrine disorders — ERR 1/Gy=0.58 (0.3; 0.87) (Ivanov et al., 1999). The highest excess relative risk per 1 Gy was found for cerebrovascular diseases — ERR 1/Gy=1.17 at the 95% confidence interval (0.45; 1.88) (Ivanov et al., 2000).

Among Chernobyl accident survivors, who had confirmed acute radiation sickness and were irradiated in dose of 1–5 Gy, there were revealed the neurophysiological markers of ionizing radiation (Loganovsky). Neurophysiological markers were: left fronto-temporal dominant frequency reduction; absolute δ-power lateralization to the left (dominant) hemisphere; relative δ-power increase in the fronto-temporal areas; absolute θ-power decrease in the left temporal region; absolute and relative α-power diffusive decrease (Loganovsky, 2002; Loganovsky & Yuryev, 2004). Neurophysiological radiation effects in human (1-5 Gy) consist of cortico-limbic dysfunction lateralised to the left, dominant, hemisphere and fronto-temporal cortical and hippocampal damage.

There were revealed also the *neuropsychological dose-effects relationships in humans* (Antipchuk, 2004): at 0.5-5 Gy dose range — dysfunction of memory interferention (r=0.6); dysfunction of associations (r=0.68), and dysfunction of senso-motor coordination (r=0.8). There were found the *neuroimaging dose-effects relationships in humans* (Bomko M, 2004) by brain magneto-resonance imaging: at 1-5 Gy: contrast index of left internal capsule (r=-0.86) and contrast index of white matter of left parietal lobe (r=-0.41); at 0.3-5 Gy: contrast index of left internal capsule (r=-0.3). These data testify to radiation-induced brain organic damage among overexposed Chernobyl accident victims and support the presences of radiation risks for the brain as well as high radiosensitivity of the brain.

Experimental behavioral studies (Varetsky et al) testify to low-dose single exposure to ionizing radiation is realized in long-term consequences on the higher nervous activity. Dose-effect

relationship has non-linear pattern, including overactivation and inhibition. Dose-effect (<1 Gy) relationship has unstable pattern. Exposure to ionizing radiation modifies stress-response for a long time. Antioxidants reduce radiation effects on the highest nervous activity testifies to an important role of oxidative mechanism of radiation effects on the highest nervous activity.

Medical lessons learnt from Chernobyl

• The radiation protection of the population in the early period after the accident was inadequate, notably in relation to prevention of the intake of radioiodine.
• Dosimetric monitoring of clean-up workers in 1986 was not properly organised leading to significant gaps in data on individual doses of this category of affected population.
• Deficiencies in providing objective and timely information about the accident and its possible consequences contributed to development of psychosocial disorders.
• Increased incidence of various diseases was identified following the accident by intensive medical examinations and improved diagnostic capability. These increases may have been caused by a combination of radiation, non-radiological factors, and a deteriorating social and economic situation.
• Most practising physicians had insufficient knowledge of the effects of radiation and how to advise the population to protect themselves.

Lessons to be learned for the future from the point of view on possible nuclear terroristic attack and radiation accident are as follows:

- optimization of governmental social policy
  - legislation improvement
  - information improvement of population
  - development of social and industrial infrastructure on radioactively contaminated areas
- complex programmes on medical, social, and psychological rehabilitation
- quantitative electroencephalogram proposed for differentiation of radiation and nonradiation brain damages in the delayed period of radiation exposure, and as a new biological dosymetry method.
- research programmes on psycho-social aftermath should be carried out
- radiation clinical and experimental neurophysiological, neurobehavior, neuroimaging, neurochemical and neuroimmunological studies are of the greatest importance for the radiation risks for the brain assessment.

The Workshop program included:

Day 1- June 10, 2004 (Plenary session):

· **10.00-10.30 Welcome address:** Ukrainian Authorities, CCMS Direction, Pilot Study co-directors, NATO Information Office in Kyiv (Dr. M. Duray).

Section 1

Summary of national experiences and evaluations of the event and its consequences, still existing problems, other, in the mostly involved Eastern Europe

- 10.30-11.00. **Ukraine**. Prof. D.A.Bazyka, Deputy Director General, Research center for Radiation Medicine - *"Health Effects of the Chernobyl NPP Accident in Ukraine"*.

· **11.00-11.30. Belarus.** Prof. J. Kenigsberg, Chairman, National Commission of Radiation Protection under Council of Ministry, *"Health Effects Due the Chernobyl Exposure in Belarus"*

- 11.30-12.00. **Russia** (Dr.I Vasilenko)

12.00-12.30 Coffee-break

Section 2 - CCMS/NATO Member Country speakers

- 12.30-13.00 Prof. A.Zapponi (Italy), "Summary of some recent relevant studies"
- 13.00- 13.30 Prof. C. Kitsos (Greece)"Cancer Bioassays with Mixtures: An Optimal Design Approach"
- 13.30-14.00 Dr. N.Nelson (USA): "Risk assessment approaches"

14.00 – 15.00 Lunch

Session 3 – Dosimetry. Epidemiology.

- 15.00-15.30 V.V. Chumak (Ukraine) *"Dosimetric support of large scale post-Chernobyl epidemiological studies*

- 15.30-15.50 Vasilenko V. V., Perevoznikov O N., Pikta V. A. (Ukraine) *"Internal irradiation population monitoring results in contaminated regions in a late stage of the ChNPP accident."*

- 15.50-16.20 I.Ya. Vasilenko ((Russian Federation)*"The Problem of Threshold on Irradiation in Small Doses"*

- 16.20-16.50 Ledoshchuk Borys O, Gudzenko N.A., Trotsuk N.K., Khukhrianskaja E.N.(Ukraine) "Epidemiological prognosis of the Chernobyl accident"

- 16.50-17.10 A.P. Kravets (Ukraine) *"Analysis of approaches for Chernobyl accident assessments and forecast"*

- 17.10-17.30. N.I. Omelyanets (Ukraine) "The problems of medical protection of the affected persons in the late period after the Chernobyl catastrophe"

- 17.30-17.50 Kryvenko S (Belarus) Oncohematological disorders in Belarus after Chernobyl

- 17.50-18.10 Shuvaeva L (Belarus)

Day 2 –June 12, 2004

Session 4 - Health Effects. Cancer and Effects in Children

- 10.00-10.20 Lukyanov nick (USA, Natl.Cancer Institute) *"Preliminary results of the US-Ukraine study on tyyroid cancer in children"*

- 10.20-10.40. V.Shestopalov, M.V., Naboka, Ye.I. Stepanova, E.A. Skvarskaya (Ukraine), Timothy A. Mousseau (USA), Y. Serkiz (Ukraine) *"Common biological consequences after Chernobyl accident for people and biota"*

- 10.40 –11.00. Prisyazhnyuk Anatoliy E. (Ukraine) *"Thyroid cancer risk in adolescents and adults living in contaminated with radio-Iode region after Chernobyl NPP Accident"*

•11.00-11.20. Kovalenko Alexander N., Belyi David A.(Ukraine) "Realized and Expected Risks of Tumor and Non-tumor Diseases Origin in Acute Radiation Sickness Survivors After the Chernobyl NPP Accident"

• 11.40-12.00. Stepanova Evgeniya I., Kolpakov I.E., Vdovenko V.Yu.(Ukraine) *"Chernobyl Accident Medical Consequences Among Children of Ukraine"*

12.00-12.30 Coffee-break

Session 4 - Health Effects. Non-cancer end-points

•12.30-13.00 Buzunov Vladimir A., Pirogova Ye. A., Tereschenko V.M., Fedirko P.A., Krasnikova L.I., Striy N.I., Voychulene Yu.S. (Ukraine) *"Basic Results of Epidemiologic Studies on Non-tumor Pathology in Chernobyl Recovery Operation Workers"*

•13.00-13.20 Pirogova Yelena A. Buzunov V.A., Krasnikova L.I., FedirkoP.A., Prikaschikova Ye.Ye., Domashevskaya T.Ye. (Ukraine) *"Non-tumor Pathology of Adult Population Evacuated from Pripyat and Chernobyl 30-km Area"*

•13.20-13.40 S.V.Klymenko *"Molecular-genetic alteration in radiation-associated acute myeloid leukaemia"* (Ukraine) – *to be defined*

•13.40-14.00. D.A. Bazyka (Ukraine) " *Immune cells recovery after radiation exposure"*

14.00 – 14.40 Lunch

•14.40-15.00. A.A. Chumak, I. V. Abramenko, P.R. Boychenko, O.Ya. Pleskach (Ukraine) *"Persisting viral infections as an additional risk factor of remote effects of irradiation"*.

• 15.20-15.50. Talko V. V., Ovsjannykova L.M., Kovalenko A.N.(Ukraine) "Oxidative homeostasis: remote effects and prognosis

•15.50-16.10. Pilinskaya M. A., Didskiy S., Dibskaya Ye., Pedan L., Shemetun Ye., Talan O.(Ukraine) *"Cytogenetical effects in Chernobyl accident victims in Ukraine"*

•16.10-16.30 Larysa Bezdrobna *"Cytogenetic effects in people working and residing without permission in ChNPP exclusion zone"*

•16.30-16.50. S.V. Andreichenko, D. V. Vatlitsov, K.S. Andreychenko (Ukraine) "The Effect of Low Doses of Ionizing Irradiation on the Spermatozoa's Enzymes and Mobility"

•16.50-17.10. Tcypriyan Victor I., Matasar I. (Ukraine) *"Alimentary Factor in Oncology Diseases Prophylaxis"*

Session 5 - Health Effects. Psychological effects

•17.10-17.30.Loganovsky Konstantyn N. (Ukraine) *"Neurophysiological Marcers of Ionizing Radiation"*

•17.30-17.50. V. V. Varetsky (Ukraine)*" Removed consequences of exposure to ionizing radiation for higher nervous activity"*.

•17.50-18.10. Prilipko Valentyna A., Prokopenko N., Petrichenko O. (Ukraine)*"The factors of social-psychological risks from the population who lived on radioactive contaminated territories"*

Day 3 – June 12, 2004

10.00 – 14.00
•10.00-10.30 Romanenko Anatoliy (Ukraine) *"Preliminary results of the US-Ukraine study on leukemia in clean-up workers"*
10.30-11.00 Masnyk Ihor (USA) *Bi-national US-Ukrainian studies on Chernobyl*

- Work in groups and preparation of the Workshop summary
- Presentation of summaries by group leaders
- Integration of the above items and Lessons for future.

Contacts:
Italy, Istituto Superiore di Sanità (ISS): Giovanni A. Zapponi alfredo.zapponi@iss.it (Coordinator)
Fax: +390649387083, Tel. +390649902915
Rome-ISS Scientific Secretariat: Ida Marcello marida@iss.it

US: Curtis Travis traviscc@icx.net (Coordinator)
US EPA Scientific Secretariat: E-mail: Schoolfield.Lynn@epamail.epa.gov

Ukraine: research Center for Radiation Medicine: Dimitry Bazyka baz@rcrm.kiev.ua
Fax: 380 44 451 8294; Tel. 380 44 213 9215; 380442139587