A fifteen-page summary composed of extracts from:

Chernobyl
Consequences of the Catastrophe for People and the Environment

by

Alexey V. Yablokov, Vassily B. Nesterenko and Alexey V. Nesterenko

Consulting Editor

Janette D. Sherman-Nevinger

Annals of the New York Academy of Sciences

Volume 1181, December 2009

330 pages, 800 references (articles published in scientific and medical journals all over the world and conference papers)

Contents

This summary does not include any material from the Foreword, Preface, Acknowledgements, Introduction, or from the chapters below.

1. Chernobyl contamination through time and space

Radioactive contamination from the Chernobyl meltdown spread over 40% of Europe (including Austria, Finland, Sweden, Norway, Switzerland, Romania, Great Britain, Germany, Italy, France Greece, Iceland and Slovenia) and wide territories in Asia (including Turkey, Georgia, Armenia, Emirates, China), northern Africa, and North America. Nearly 400 million people resided in territories that were contaminated with radioactivity higher than 4Bq/m^2 (0.11Ci/km^2) from April to July 1986. Nearly 5 million people (including more than 1 million children) still live with dangerous levels of radioactive contamination in Belarus, Ukraine and European Russia.

Most of the the Chernobyl radionuclides (up to 57%) fell outside the former USSR and caused noticeable radioactive contamination over a large area of the world – practically the entire Northern hemisphere. There is **no reasonable explanation for the fact that the IAEA and the WHO (Chernobyl Forum 2006) have completely neglected** the consequences of radioactive contamination in other countries, which received more than 50% of the Chernobyl radionuclides, and addressed concerns only in Belarus, Ukraine and European Russia.

Some 40% of Europe has been exposed to Chernobyl's Cs-137 at a level of 4-40 kBq/m^2 (0.11 – 1.08 Ci/km^2). Assuming that about 35% of the European population lives in this territory (where radionuclides fell on sparsely populated mountain areas) and counting the total European population at the end of the 1980s, we can calculate that **nearly 550 million Europeans live in noticeably contaminated areas and nearly 15 million in areas where the Cs-137 contamination is higher than 40Bq/m^2 (1.08 Ci/km^2)**

In areas contaminated above 1Ci/km^2 (a level that undoubtedly has statistical impact on public health) there are no fewer than 1 million children; and evacuees and liquidators have had no fewer than 450,000 children.

Levels of radioactive contamination in the **first days and weeks after the catastrophe were thousands of times higher than those recorded 2 or 3 years later**. Contamination will exist beyond the foreseeable future not less than 300 years for Cs-137 and Sr-90, more than 200,000 years for Pu and several thousand years for Am-241.

Tens of millions of people, not only in Belarus, Ukraine and Russia but **worldwide will live under measurable chronic radioactive contamination for many decades**. Even if the level of external radiation decreases in some areas, very serious contamination in the first days and weeks after the explosion together with decades of additional and changing conditions of radioactivity will have an inevitable negative impact on public health.

Uneven/spotty distribution of Chernobyl radioactive fallout has attracted too little attention. Small local highly radioactive "**hot spots" measure tens to hundreds of meters across and have levels of radioactivity ten times higher than the surrounding areas**. The problem of "Chernobyl dust" or "hot particles" has likewise been neglected.

When the reactor exploded, it expelled not only gases and aerosols but also particles of U fuel melted together with other radionuclides – firm **hot particles**. When absorbed into the body (with water, food or inhaled air), such particles **generate high doses of radiation even if an individual is in an area of low contamination**. Fine particles easily penetrate the lungs whereas larger ones are concentrated primarily in the upper respiratory system. Studies of the formation and disintegration of hot particles, their properties and their impact on the health of humans and other living organisms are meager and totally inadequate.

Lastly, **the impact of the 2400 tons (some authors estimate 6720 tons) of lead** dumped from helicopters onto the reactor to quench the fire has not been adequately evaluated. A significant part of this lead was spewed out into the atmosphere as a result of its fusion, boiling and sublimation in the burning reactor.

2. Chernobyl's public health consequences: some methodological problems

It is very difficult to draw a complete picture of Chernobyl's influence on public health for various reasons: **official secrecy and falsification** of medical records by the USSR for the first 3.5 years after the catastrophe (including a ban on associating disease with radiation); **absent or grossly inadequate data on exposures**; and the expressed desire of **national and international official organizations and the nuclear industry to minimize the consequences** of the catastrophe.

The scientific fallacy of a simple correlation demanded by IAEA, WHO and UNSCEAR.

A simple correlation between level of radiation and effect on health cannot be made because the true radioactive impact of the accident on individuals or groups is not, and *cannot be known*, for the reasons set out above and because of further objective difficulties in:

- Reconstructing doses from radionuclides released in the first days, weeks and months after the accident
- Calculating the influence of hot particles, for different radionuclides owing to their physical and chemical properties
- Determining levels of external and internal radiation for the average person and/or group because "doses" were not directly measured and calculations were based on dubious assumptions
- Determining the influence of the "leopard spot" distribution of radionclides, and as a result the high probability that individual doses of personal radiation are both higher or lower than "average" doses for the territory
- Accounting for all the multiple radionuclides in a territory
- Accounting for the movement of radionuclides from soil to food chains, levels in each animal and plant species
- Determining the health of individuals who have moved away from contaminated areas.

It is methodologically incorrect to combine imprecisely defined ionizing radiation exposure levels for individuals or groups with the much more accurately determined impacts on health and to demand a statistically significant correlation.

Dismissal of unique and valuable data

An enormous body of data from Belarus, Ukraine and European Russia **has been dismissed on the grounds of failure to observe "scientific protocols."** Usually this means that there was no statistical processing of the received data. The doctors and scientists who collected such data were, first of all, trying to help the victims, and secondly, owing to lack of time and resources, not always able to offer their findings for publication. But this is valuable and unique data that should be used. In the last decade, as information has accumulated, a range of values has been found to be within the limits of true statistical significance.

There have been advances in the statistical processing of biological and epidemiological data especially where very large populations are involved (and one of the authors has considerable experience in this area) and alternative approaches have been developed which allow reliable, statistically significant conclusions.

"Fallout from Chernobyl adds only about 2% to global radioactive background"

This is a misleading comment that has been much quoted in order to dismiss the possibility of significant health effects. For many populations in the Northern hemisphere the Chernobyl doses would be many times higher compared with the natural background, whereas for others (mostly in the Southern hemisphere) it can be close to zero. Averaging Chernobyl doses globally is like averaging the temperature of hospital patients.

Another argument is that natural background radiation is many times higher than the average Chernobyl fallout in various regions of the world and humans successfully inhabit such areas. Based on animal studies of radiosensitivity, it would take 400 years for the local populations in Chernobyl contaminated areas (20 generations) to become less radiosensitive.

We simply do not know when only a small amount of additional Chernobyl radiation will cause an overflow of damage and irreversible change in the health of humans and nature.

3. General morbidity, impairment and disability after the Chernobyl catastrophe

In all cases, when comparing the territories heavily contaminated by Chernobyl's radionuclides with less contaminated areas that are characterized by a similar economy, demography and environment, there is a marked increase in general morbidity in the former. Certainly there is no direct proof of the influence of the Chernobyl catastrophe on these figures, but the question is: what else can account for the increased illness and disability that coincide precisely in time and with increased levels of radioactive contamination, if not Chernobyl?

The IAEA and WHO suggested (Chernobyl Forum 2006) that the increased morbidity is partly due to social, economic, and psychological factors. Socioeconomic factors cannot be the reason because the compared groups are identical in social and economic position, natural surroundings, age composition, etc and differ only in their exposure to Chernobyl contamination.

According to data from the Belarus Ministry of Public Health, just before the catastrophe **(in 1985), 90% of children were considered "practically healthy". By 2000, fewer than 20% were considered so,** and in the most contaminated Gomel Province, fewer than 10% of children were well (Nesterenko, 2004).

From 1986 to 1994 in Belarus, **the overall death rate for newborns was 9.5%. The largest increase (up to 205%)** found in the most contaminated Gomel Province (Zykovich *et al*, 1996) was due primarily to disease among the growing number of premature infants.

From 1997 to 2005, the **number of the "practically healthy" children** in heavily contaminated areas of Ukraine **decreased more than six fold** – from 3.2% to 0.5% (Horishna, 2005).

All the **Russian liquidators**, mostly young men, were initially healthy. Within 5 years after the catastrophe, 30% of them were officially recognized as "sick"; **10 years after, fewer than 9% of them were considered "healthy**" (Ivanov *et al*, 2004; Prybylova *et al* 2004).

Great Britain. In Wales, one of the regions most heavily contaminated by Chernobyl fallout, **abnormally low birth weights** (less than 1500 g) were noted in **1986 and 1987** (Busby, 1995).

4. Accelerated aging as a consequence of the Chernobyl catastrophe

Accelerated aging is one of the well known consequences of exposure to ionizing radiation. This phenomenon is apparent to a greater or lesser degree in all of the populations contaminated by the Chernobyl radionuclides.

Children from the contaminated areas of **Belarus have digestive tract epithelium characteristic of senile changes** (Nesterenko, 1996; Bebeshko *et al,* 2006).

The **biological age** of inhabitants from the radioactive contaminated territories of Ukraine **exceed their calendar ages by 7 to 9 years** (Mezhzherin, 1996)

Early aging is a typical characteristic seen in liquidators, and many of them **develop diseases 10-15 years earlier than the average population**. The biological ages of liquidators calculated by the characteristics of aging are 5 to 15 years older than their calendar ages (Gadasyna, 1994; Romanenko *et al*, 1995, Tron'ko *et al*, 1995; Ushakov *et al*, 1997).

An accelerated rate of aging measured in 5 year intervals marked by **biological and cardiopulmonary changes** (and for 11 years, physiological changes) was found in **81% of men and 77% of women liquidators** (306 surveyed) (Polyukhov *et al*, 2000).

5. Nonmalignant diseases after the Chernobyl catastrophe

There was widespread damage to the people living in the contaminated territories. Nearly all physiological systems were adversely affected, resulting in consequences ranging from impairment to death. These disorders cannot be attributed to socioeconomic factors or behavioural stress factors. The studies control for these factors through comparisons between areas of low and high contamination with identical or similar socioeconomic conditions, through comparisons before and after the catastrophe and in some cases, through correlation with levels of contamination measured in the body. The disorders are real and documented.

This section describes the spectrum and the scale of the nonmalignant diseases that have been found among exposed populations. Adverse effects as a result of Chernobyl irradiation have been found in every group that has been studied. Brain damage has been found in individuals directly exposed – liquidators and those living in the contaminated territories, as well as in their offspring. Premature cataracts; tooth and mouth abnormalities; and blood, lymphatic, heart, lung gastrointestinal, urologic, bone, and skin diseases afflict and impair people, young and old alike. Endocrine dysfunction, particularly thyroid disease, is far more common than might be expected, with some 1,000 cases of thyroid dysfunction for every case of thyroid cancer, a marked increase after the catastrophe. There are genetic damage and birth defects especially in children of liquidators and in children born in area with high levels of radioisotope contamination. Immunological abnormalities and increases in viral, bacterial and parasitic diseases are rife among individuals in the highly contaminated areas. For more than 20 years, overall morbidity has remained high in those exposed to the irradiation released by Chernobyl. The negative health consequences of the catastrophe are amply documented in this chapter and concern millions of people.

5.1 Blood and lymphatic system diseases

For both children and adults, diseases of the blood and the circulatory and lymphatic systems are among the most widespread consequences of the Chernobyl radioactive contamination and are a leading cause of morbidity and death for individuals who worked as liquidators. The picture is far from clear but one of the common reasons for functional impairments is radioactive destruction of the endothelium, the covering surface of vessels.

5.1.1 Diseases of the blood and blood forming organs

The incidence of diseases of the blood and blood forming organs was **3.8 fold higher among evacuees** 9 years after the catastrophe. It was **2.4 fold higher for inhabitants of the contaminated territories** than for all of the population of Belarus; these rates were respectively 279, 175, and 74 per 10,000 respectively (Matsko, 1999).

Children in the heavily contaminated territories (Ukraine) have a level of **free oxidizing radicals in their blood that is significantly higher** than in those in the less contaminated territories. 1,278 plus or minus 80 compared with 445 plus or minus 36 measured as impulses per minute (Horishna, 2005)

Diseases of the blood and circulatory system for people living in the contaminated territories (Ukraine) **increased 11 to 15 fold for the first 12 years** after the catastrophe (1988-1999) Prysyazhnyuk *et al* 2002).

Critically low lymphocyte counts were seen in children in the contaminated districts of Bryansk Province (Russia) over a 10 year survey after the catastrophe (Luk'yanova and Lenskaya, 1996).

5.1.2 Cardiovascular diseases

Incidence of **hemorrhages in newborns** in the contaminated Chechersky District of Gomel Province (Belarus) is **more than double than before the catastrophe** (Kulakov *et al*, 1997).

In the observation period 1992-1997, there was a **22.1% increase** in the incidence of fatal cardiovascular disease **among liquidators compared to 2.5% in the general population** (Belarus) (Pflugbeil et al, 2006).

5.2 Genetic changes

Changes in genetic structures in both reproductive and somatic cells determine and define the occurrence of many diseases. **Ionizing radiation causes damage to hereditary structures**. The huge collective dose from the Chernobyl catastrophe (127-150 million persons/rad) has resulted in **damage that will span several generations,** causing changes in genetic structures and various types of mutations: genomic mutations (change in the number of chromosomes), chromosomal mutations (damage to the structure of chromosomes - translocations, deletions, insertions and inversions), and small (point) mutations. The increase in chromosomal damage which is observable everywhere in the contaminated territories is a measure of high genetic risk as well as the risk of developing many illnesses. The overwhelming majority of Chernobyl-induced genetic changes will not become apparent for several generations**. Only 10% of all expected Chernobyl genetic damage occurred in the first generation (Pflugbeil *et al*, 2006).** The Chernobyl radiation is genetically much more dangerous than that released in Hiroshima and Nagasaki as the quantity of radionclides emitted was several hundred fold higher and there were many more different kinds of radionuclides. The genetic consequences of the Chernobyl catastrophe will impact hundreds of millions of people including:

- Those exposed to the first release of short lived radionuclides which spread worldwide
- Those who live and will continue to live in territories contaminated by Sr90 and Cs137 as it will take no fewer than 300 years for the radioactive level to decrease to background level
- Those who will live in the territories contaminated by Pu and Am as millennia will pass before that deadly radioactivity decays
- Children of irradiated parents for as many as 7 generations (even if they live in areas free from Chernobyl radionuclide fallout.

Changes in frequency of mutations
In 1991 **in Norway, a 10-fold increase in the number of chromosomal aberrations** was found in 56 adults compared to controls (Brogger et al, 1996, Schmitz Feuerhake, 2006).

The frequency of occurrence of **chromosomal aberrations increased 2-4 fold** among those individuals in Chernobyl territories **(Russia)** with Cs-137 levels of contamination above 3 Ci/Km^2 (Bochkov, 1993).

In 1987 in **Austria, among 17 adults examined there was a 4-6 fold increase in the number of chromosomal aberrations**, and in two individuals, examined before and 1 year after the catastrophe, there was an 11 fold increase (Pohl-Ruling *et al*, 1991).

Genomic mutations
Trisomy 21 **(Down syndrome) Belarus. There was a 49% increase in the most contaminated 17 districts** in 1987-1988 and an increase of 17% for the whole country for 1987-1994 (Lazjuk *et al*, 1997).

There was a **doubling of Down syndrome in Lothian, Scotland** one of the territories contaminated by Chernobyl (Ramsey *et al*, 1991).

Changes in satellite DNA
The number of mutations due to Chernobyl radiation has increased not only in somatic, but also in germ cells. The level of **small mutations in minisatellite DNA** in children born to irradiated parents and living in **contaminated territories of Belarus and Ukraine is almost twice that of children in Great Britain** (Dubrova, 2003).

Genetically caused Congenital Developmental Abnormalities (CDAs)
The annual general morbidity among **children born to irradiated fathers** from 2000 to 2005 was higher in Ukraine as a whole **(1,135-1,367 per 10,000 vs the Ukraine average of 960-1,200).** Among these children, only 2.6-9.2% were considered "practically healthy" vs 18.6-24.6% in the control group (National Ukraine Report, 2006).

5.3 Diseases of the endocrine system

All physiological functions dependent on the organs of internal secretion (pancreas, parathyroid, thyroid and adrenal glands, ovaries and testes) which control multiple functions, must coordinate to sustain normal development. Chernobyl's radioactive contamination has adversely impacted the function of the entire endocrine system with multiple serious health effects including thyroid disease, immune dysfunction, diabetes, impaired sexual and reproductive function and impaired physical and mental development. Individuals living in the contaminated territories have 50% lower sympathetic activity and 36% lower adrenal cortical activity. Children in the contaminated territories had significantly lower cortisol blood levels. For every case of thyroid cancer there are about 1000 cases of other kinds of thyroid gland pathology. Damage to the thyroid gland of the unborn or the neonate may result in diminished mental capacity for life.

Six years after the catastrophe, incidence of **endocrine organ illnesses was 3-fold higher in the heavily contaminated territories of Belarus** (Shilko*et al*, 1993).

From 1988 to 1999 endocrine system morbidity in contaminated territories of **Ukraine increased up to 8-fold** (Prysyazhnuuk et al, 2002).

Fifteen years after the catastrophe overall endocrine system morbidity in the **contaminated territories of Russia exceeded the provincial level 2.6-fold** (Sergeeva et al, 2005).

5.4 Immune system diseases

The lymphatic system – the bone marrow, thymus, spleen, lymph nodes, and Peyer's patches – has been impacted by both large and small doses of ionizing radiation from Chernobyl fallout. The quantity and activity of various groups of lymphocytes and thus the production of antibodies, including various immunoglobulins, stem cells and thrombocytes are altered. The destruction of the immune system leads to immunodeficiency and an increase in the frequency and seriousness of acute and chronic diseases and infections, as is widely observed in Chernobyl irradiated territories. This immune suppression is known as "Chernobyl AIDS".

Antitumor immunity in children and evacuees (Belarus) was signficantly lower in heavily contaminated territories (Nesterenko *et al*, 1993).

Significant changes in all parameters of cellular immunity (in the absence of humoral ones) were found in children born to liquidators in 1987 in Belarus (Arynchin et al, 1999).

Significant impairment of cellular and humoral immunity was found in areas of higher levels of radionuclides in Ukraine (Soloshenko, 2002).

Children living in heavily contaminated territories of Russia have **generalized and specific immunity suppression and malfunction of their antioxidant and sympathetic adrenal systems** (Terletskaya, 2003).

5.5. Respiratory system diseases

Illnesses of the upper respiratory system (nasopharynx and bronchial tubes) were the initial consequences of Chernobyl irradiation for the general population and the liquidators in the first days and weeks afer the catastrophe. In some years, the incidence of bronchopulmonary illnesses decreased but the severity increased, reflecting significant impairment of the immune and hormonal systems. Some 10 to 15 years later, respiratory morbidity in Belarus, Ukraine and Russia remained significantly higher in the contaminated territories.

In the first three years after the catastrophe, **respiratory illnesses in Belarus children** from territories contaminated at a level of 15-40 Ci/Km2 were **3.5-fold more common than in less contaminated territories,** and from 1990 to 193, 2.5-fold more common (Gudkovsky *et al*, 1995).

Non-infectious respiratory disorders in neonates born to mothers from the contaminated territories in Russia were encountered **9.6 times more often** than before the catastrophe (Kulakov *et al*, 1997).

The frequency of **chronic bronchopulmonary illnesses in liquidators** in Russia increased significantly over the first 15 years after the catastrophe with an **increase up to 10-fold** for some illnesses (Tseloval'nykova *et al,* 2003).

5.6 Urogenital tract disorders and reproductive disorders
Irradiation directly damages the kidneys, bladder and urinary tract, as well as the ovaries and testicles, which not only are subject to direct radiation effects, but are indirectly affected through hormonal disruption. These disorders in structure and function result in damage to the reproductive process.

Up until 2000, children born after the catastrophe in heavily contaminated territories (Belarus) had more **reproductive organ disorders** than those born in less contaminated areas: **5-fold higher for girls and 3-fold higher for boys** (Nesterenko *et al*, 1993).

The incidence of **endometriosis increased almost 2.5-fold** in Gomel, Mogilev and Vitebsk (Belarus) cities from 1981 to 1995.

Primary infertility in the contaminated areas increased 5.5-fold in 1991 compared with 1986. Among the irrefutable reasons for infertility are **sperm pathologies which increased 6.6-fold** (Shilko *et al*, 1993).

From 1988 to 1999 the incidence of **urogenital diseases** in the populations of contaminated territories **more than doubled** (Prysyazhnyuk *et al*, 2002).

A total of **54.1% of pregnant women** from the contaminated territories had **pre-eclampsia, anemia and destruction of the placenta (controls 10.3%); 78.2% had birth complications** and excess bleeding (**2.2-fold higher than controls**) (Luk'yanova, 2003; Sergienko, 1997, 1998).

From1988 to 2003, **urogenital morbidity among male liquidators** who worked in 1986 and 1987 **increased 10-fold** (Baloga, 2006).

5.7 Bone and muscle disease
Osteoporosis results from an imbalance between the formation of bone and the natural reabsorption process. Such imbalance results from either hormonal disorders or direct damage by irradiation to the cellular predecessors of osteoclasts and osteoblasts (Ushakov *et al*, 1997). Bone and muscle disease are not insignificant. The loss of teeth leads to deterioration in a person's ability to eat and secondary adverse effects. Chronic boen and muscle pain leads to loss of function and curtailment of activities needed to sustan life. The effects are especially serious for children when osteomuscular defects impede growth and activity.

Muscular system and connective tissue diseases in liquidators increased 2.3-fold from 1991 ot 2001 in Ukraine (Borysevich and Poplyko, 2002).

Cs-137 incorporated in the placenta at a level of 0.9-3.25 Bq/kg leads to **weakness of tubular bone structures and destruction of the spinal cartilage** (Ukraine) (Arabskaya *et al*, 2006).

Osteoporosis was found in 30-88% of liquidators who were examined in Russia (4 studies cited).

5.8 Diseases of the nervous system and sense organs and their impact on mental health
Since the Chernobyl catastrophe it is clear that low dose rates of radiation have enormous impact on the fine structures of the nervous system, on higher nervous system activities, and ocular structures, as well as on neuropsychiatric disorders that are widespread in the contaminated territories. There is a growing body of evidence supporting radiosensitivity of the brain (Nyagu and Loganovsky, 1998). Low levels of ionizing radiation cause changes in both the central and the autonomic nervous systems and can precipitate radiogenic encephalopathy. Throughout the more contaminated territories, visual and hearing abnormalities occur with greater frequency than in the less contaminated areas: premature cataracts, vitreous degeneration, refraction errors, uvitis, conjunctivitis and hearing loss.

A longitudinal study in Belarus showed that the incidence of **perinatal encephalopathy after 1986 was 2 – 3 times higher** than before the catastrophe (Kulakov *et al*, 2001).

In a comparison between 340 **agricultural machine operators** from the heavily contaminated Gomel Province in Belarus and a similar group of 202 individuals from the vicinity of less contaminated Minsk, the first group exhibited a **6-fold higher incidence of vascular brain pathology** (Ushakov *et al*, 1997).

Electroencephalograms (EEGs) for **97%** of 70 surveyed evacuees children indicated **structural and functional immaturity of subcortical and cortical brain structures;** that is, **only two out of these 70 children had normal EEGs** (Horishna, 2005).

Retinal pathology in children in Gomel Province **increased about 3-fold** in the first 3 years after the catastrophe compared to 1985 (Byrich *et al*, 1999).

In Norway, cataracts in newborns occurred twice as often 1 year after the catastrophe (Irgens *et al*, 1991).

5.9 Digestive system and visceral organ disease

There was an immediate increase in the incidence of digestive tract diseases among liquidators and a rise in the number of congenital digestive system malformations in babies born in the contaminated territories. The assumption appears proven that low level radiation acts in some way to directly affect the function of the gastrointestinal tract epithelium - and not only during intrauterine development.

Digestive system morbidity in **liquidators (Russia) increased 7.4-fold over a 9 year period** (Baleva *et al*, 2001)

Of 135 surveyed juvenile evacuees from Bragin City (Belarus) and the highly contaminated territories of Stolinsk District, Brest Province, **40% has gastrointestinal tract illnesses** (Belyaeva *et al*, 1996).

Atrophy of the stomach mucosa occurred 5 times more often, and **intestinal metaplasia twice as often** in children living in areas of Ukraine contaminated at a level of 5-15 kBq/m^2 than in a control group (Burlak *et al*, 2006).

5.10 Skin diseases associated with the Chernobyl catastrophe

The post-Chernobyl period has seen an increase in diseases of the skin and subcutaneous tissues in children and liquidators. Diseases of the skin reflect not only the effect of external irritants but also diseases of internal organs and the effects of organic and inorganic agents that are absorbed internally.

Skin diseases among evacuees living in the heavily contaminated territories from 1988 to 1999 were **more than 4-fold higher** than in the less contaminated areas (Prysyazhnyuk *et al*, 2002).

Dermatological pathology was found in 60% of children and teenagers in Gordeevka, Bryansk Province, Russia, which is one of the most contaminated districts (Kyseleva and Mozzherova, 2003).

Among the **97% of liquidators who developed psoriasis** after the catastrophe the psoriasis was always combined with functional impairment of the nervous system and with gastrointestinal disorders (Malyuk and Bogdantsova, 2001).

5.11. Infections and parasitic infestations

Ionizing radiation is a powerful mutagenic factor. Chernobyl radionuclide contamination impacted microbial flora and fauna and other of our symbionts (parasites and commensals) and changed our biological community. There is evidence of increased incidence and severity of diseases characterized by intestinal toxicoses, gastroenteritis, bacterial sepsis, viral hepatitis, and respiratory viruses in areas contaminated by Chernobyl radionuclides. (Many studies cited). The data reflect activation and dispersion of dangerous infections. Whether this is due to mutational changes in the disease organisms rendering them more virulent, impaired immunological defences in the populations, or a combination of both is not fully answered.

Herpes viral diseases doubled in the heavily contaminated territories of Gomel and Mogilev Provinces (Belarus) 6 to 7 years after the catastrophe compared with the rest of the country (Matveev, 1993).

In Gomel Province, **hepatitis B and C infections in adults and teenagers** rose significantly after 1986. Among 2,653 individuals examined, the incidence increased from **17 cases per 100, 000 in 1986 to 35 in 1990.**

By 1995, **infectious and parasitic diseases in children were over 5 times more common in the heavily contaminated territories** compared with less contaminated areas. In 1998 these territories did not differ in terms of the occurrence of such diseases (Baida and Zhirnosekova, 1998).

5.12 Congenital malformations (CM)

Wherever there was Chernobyl radioactive contamination there was an increase in the number of children with hereditary anomalies and congenital malformations. These included previously rare multiple structural impairments of the limbs, head and body. (Various studies cited). The occurrence of CMs continues to increase in several of the contaminated territories and correlates with the levels of irradiation. Thus the link between congenital and genetic defects and Chernobyl irradiation is no longer an assumption, but is proven.

The incidence of CMs increased significantly **from 5.58 per 1000 before the catastrophe to 9.38** for the years from 2001 to 2004 (National Belarussian Report, 2006).

Disability owing to congenital defects in children **newborn to 15 years of age increased more than 3-fold in the Ukraine** from 1992-1993 to 2000-2001; from 10 to 31 per 10,000 (UNICEF, 2005).

CMs in contaminated regions (Russia) **increased 3- to 5-fold in 1991 and 1992 compared with the pre-catastrophe level,** with a noticeable increase in anomalies of the genitals, nervous system, sense organs, bone, muscular and digestive systems and congenital cataracts (Kulakov *et al*, 2001).

Incidence of **neural tube defects in Turkey (three regions studied) increased between 2- and 5-fold** after the catastrophe (Hoffman, 2001; Schmitz-Feuerhake, 2006).

6. Oncological Diseases after Chernobyl

The most recent forecast by international agencies predicted there would be between 9000 and 28,000 fatal cancers between 1986 and 2056, obviously underestimating the risk factors and the collective doses. On the basis of I-131 and Cs 137 radioisotope doses to which populations were exposed and a comparison of cancer mortality in the heavily and less contaminated territories and pre- and post-Chernobyl cancer levels, a more realistic figure is 212,000 to 245,000 in Europe and 19,000 in the rest of the world. High levels of Te-13, Ru-103, Ru-106 and Cs 134 persisted months after the Chernobyl catastrophe and the continuing radiation from Cs-137, Sr-90, Pu and Am will generate new neoplasms for hundreds of years.

Selection of study findings

For the period 1990-2000, **cancer mortality in Belarus** increased by 40%. The increase was a maximum in the most highly contaminated Gomel province and lower in the less contaminated Brest and Mogilev provinces 52%, 33% and 32% respectively (Okeanov et al, 2004).

More than **1000 cancer deaths in Norland Province, Sweden,** between 1986 and 1999 have been attributed to the Chernobyl fallout (Abdelrahman, 2007).

After 20 years the **incidence of thyroid cancer** among individuals under 18 years of age at the time of the catastrophe **increased more than 200-fold** (National Belarussian Report, 2006).

In the **Marne-Ardennes provinces (France) cancer incidence** increased 360% in women and 500% in men between 1975 and 2005 (Cherie-Challine et al, 2006). From 1985-1989 to 1990-1992 in **Connecticut, USA, rates**

of thyroid cancer for all age groups increased by 23% (from 3.46 to 4.29 per 100,000, after 10 previous years without change (Reid and Mangano, 1995) .

In Greece, infants born between 1.7.86 and 31.12.87, exposed to Chernobyl fallout in utero, **had 2.6 times the incidence of leukemia** compared to children born between 1.1.80 and 31.12.85 and between 1.1.88 and 31.12.90. (Petridou et al, 2004)

In Belarus, lung cancer morbidity among the evacuees (about 32,000 examined) was fourfold higher than the country average (Marples, 1996)

In **Mogilev province (Belarus) breast cancer increased fourfold** from the period 1993-1996 to the period 1989-1992. (Putyrsky and Putyrsky, 2006)

In the **heavily contaminated Gomel province (Belarus)** there was a marked increase in the number of cases of **intestinal, colon, breast, bladder, kidney and lung cancers** and the occurrences correlated with the level of Chernobyl contamination (Okeanov *et al,* 1996, Okeanov and Yakymovich, 1999).

7. Mortality after the Chernobyl Catastrophe

A detailed study reveals that 3.8-4.0% of all deaths in the contaminated territories of Ukraine and Russia from 1990 to 2004 were caused by the Chernobyl catastrophe. The lack of evidence of increased mortality in other affected countries is not proof of the absence of effects from the radioactive fallout. Since 1990, mortality among liquidators has exceeded the mortality rate in corresponding population groups. From 112,000 to 125,000 liquidators died before 2005 – that is, some 15% of the 830,000 members of the Chernobyl cleanup teams. There are many findings of increased antenatal, childhood and general mortality in the highly contaminated territories that are most probably associated with irradiation from the Chernobyl catastrophe. Significant increases in cancer mortality were observed for all irradiated groups. (see summary of Chapter 6 above) The calculations suggest that the Chernobyl catastrophe has already killed several hundred thousand human beings in a population of several hundred million that was unfortunate enough to live in territories affected by the fallout. The number of Chernobyl victims will continue to grow over many future generations.

In 1987 in the 10 most affected districts of **Bavaria, there was a 45% increase in the proportion of stillbirths** (Scherb et al, 2000).

Changes in the **sex ratio and the stillbirth** odds ratio for gender were significant for **Denmark, Germany, Hungary, Norway, Poland, Latvia and Sweden** (Scherb and Wiegelt, 2000).

Great Britain. Ten months after the catastrophe, **a significant increase in perinatal mortality** was found in the two most contaminated areas of the country (Bentham, 1991).

Sweden. Infant mortality increased immediately after the catastrophe and **increased significantly in 1989-1992** (Korblein, 2008).

Mortality among male Ukrainian liquidators increased more than five fold from 1989-2004 from 3.00 to 16.6 per 1000 as compared to 4.1 to 6.0 per 1000 in other men or working age (Horishna, 2005).

In Kaluga province, Russia, **87% of all liquidators who died** in the first 12 years after the catastrophe were **30 -39 years old** (Lushnykov and Lanstov, 1999).

Belarus. The average life expectancy of populations living in territories with Cs 137 ground contamination above 555kBq/m^2 (15Ci/km^2) was **8 years less than the national average** (Antypova and Babichevskaya, 2001).

Ukraine. According to official data, the **general mortality rate** in the heavily contaminated territories was 18.3 per 1000 in 1999, some **28% higher than the national average** of 14.8 per 1000 (Reuters, 2000).

Russia. From 1994-2004, the general mortality in highly contaminated districts of Bryansk Province increased by 22.5%, primarily **in the age group 45-49 years, where it increased by 87%** (Kashyryna, 2005; Sergeeva et al, 2005).