The possibility of determining of anomalies and pathologies caused by the non-ionizing radiation in the offspring of liquidators worked at the Chernobyl nuclear plant

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Abstract: Hereditary effects of radiation on people are not revealed and estimations for humans have been carried out by extrapolation from mutagenesis of irradiated mice (UNSCEAR). Nevertheless, in Russia, Ukraine and Belarus disturbance and pathologies are found in the children of liquidators of the accident at the Chernobyl atomic power station. Authors connect effects only with irradiation (basically in low doses) though there were also other factors. So, the psychogenic stress leads to genomic and chromosomal damages and strengthens the mutagens. For the offspring of parents with psychoemotional stress, depression, etc. the set of alterations and diseases is registered. For liquidators probably there is also the influence of other nonradiation factors. The conclusion is made that effects on the children of liquidators have mainly not a radiation cause. Families of liquidators were in a stress (together with effects of other agents on fathers) and could give birth to less healthy children.

Keywords: liquidators; Chernobyl; offspring; radiation; genetic effects.

1. Introduction

The accident at the Chernobyl nuclear power plant (ChNPP) was the second most important event (after the atomic bombings in Japan) and induced epidemiological studies in radiation genetics. Hereditary effects of radiation were originally shown in Drosophila HJ Muller (1927) and in mice L.B. Russell and W.L. Russell (1950's) but were not registered indisputably on the human population in spite of nearly 60 years research activities. Nevertheless, international organizations recognize that the genetic effects of radiation exposure existed in human population, although they were not registered, because human beings in this regard are no exception to the whole biota. The only point is that the real epidemiology couldn't submitted their relevant data on this issue [UNSCEAR, 2001; COMARE, 2002; BEIR, 2006; UNSCEAR, 2006a; UNSCEAR, 2006b; ICRP, 2007]. Unfortunately, the accurate data wasn't obtained due to the offspring victims research activities in Japan and the study of children suffered from radiochemotherapy. Attempts to identify radiation-induced changes in the offspring of the nuclear industry employees also have not produced proper data yet. (We have listed the most eminent reports which results are in international organizations feasibility range.).

Therefore, the evaluation of the "doubling dose" in humans (doses that would increase the frequency of spontaneous mutation for a single generation doubly) was originally applied to the frequency of mutation in the seven reference genes in irradiated mice. Doubling dose is composed of 1 Gy per generation in 1972-1977 years and was a simple extrapolation of effects in mice to the effects in humans. The methodical approach has been slightly modified by using the mutation model "man - mouse" in 2001 year [UNSCEAR, 2001]. In this model the initial background was taken as the frequency of hereditary diseases in humans and the frequency of mutations in the gene locus in mice was assigned as an induced radiation effect. In 2001 this model obviously was not based on the assessing of some radioepidemiological values. Moreover, the value of the doubling dose has remained virtually unchanged (formally in 2001year it was 0.82 Gy, but UNSCEAR proposed that an old dose of 1 Gy must be settled to avoid "unnecessary exactly") [UNSCEAR, 2001; COMARE, 2002; BEIR, 2006; UNSCEAR, 2006a; UNSCEAR, 2006b; ICRP, 2007].

2. The international organizations proposed regulations of no registered transgenerational effects of radiation exposure on human beings

In the UNSCEAR report devoted to genetic effects of radiation exposure [UNSCEAR, 2001] we could pointed out that epidemiological studies have failed to provide data to radiation genetics from hereditary effects of radiation exposure.

In general BEIR-VII [BEIR, 2006] and its subsequent amendment in 2010 there repeated UNSCEAR regulations. In ICRP 103 (2007) in section 3.2.2, paragraph 74 (p. 53) it's stated:

> "Although it remains the case that no human studies provide direct evidence of a radiation associated excess of heritable disease, the data from experimental animals provide a compelling reason for ICRP to continue to make best use of advances in genetics in order to improve its estimate of these risks".

In COMARE-VII it's indicated that there is no reliable information about heritable genetic effects relevant to irradiated parents [COMARE, 2002].

3. Canonical risk assessment of hereditary genetic effects of radiation exposure

Canonical evaluation of genetic risks is represented in Table. 1.

Table 1 Radiation risk of hereditary genetic effects

Type of disease	Background frequency (per million live births)	Risk (1 Gy per million children)
Mendelian autosomal dominant and X-linked	16.500	~750 до 1500
Mendelian autosomal recessive	7500	0
Chromosomal	4000	—
Multifactorial chronic disease	650.000	от ~250 до 1200
Congenital anomalies	60.000	~2000
In total	738.000	от ~3000 до 4700
In total at 1 Gy as a percentage of the background	—	от ~0,41 до 0,64

Canonical evaluations of genetic risks represented in Table 1 show us that attempts to detect an increase in the incidence of congenital malformations in any real epidemiological study is almost hopeless. Although inherent defects have in itself the multifactorial nature [UNSCEAR, 2001; UNSCEAR, 2006a; ICRP, 2007] we can see from Table. 1 that irradiation of the parents even at a dose of 1 Gy per 60 congenital abnormalities in one thousand babies will be added only two more abnormalities (3,3%).

As a result UNSCEAR [UNSCEAR, 2001] and ICRP [ICRP, 2007] submit the following average estimates of risk for populations irradiated in each generation (in 1 million births):

- The risk of Mendelian diseases - 0,19% for 1 Gy;
- The risk of multifactorial diseases - 0,08% for 1 Gy;
- The risk of congenital anomalies of -0.27% for 1 Gy;
- The overall risk for all disease classes - 0,54% per 1 Gy.

In this way it seems incredible that we can identify inherited genetic effects of irradiation exposure to people with small doses of radiation and with low LET (low dose - is 0.1 Gy according to BEIR-VII [BEIR, 2006] and ICRP [ICRP, 2006; ICRP, 2007)], and up to 0.2 Gy according to UNSCEAR [UNSCEAR, 2000a; UNSCEAR, 2001; UNSCEAR, 2006b].

4. Cohort of liquidators: characteristics, type of exposure and dose

Basic information about the history of the development, research and characteristics of the cohort of liquidators of the Chernobyl accident, on their accumulated doses and irradiation regimes can be found in

the report LA Ilyin and VP Kryuchkov et al [Il'yin, 1995; Il'yin et al., 1995 and Aleksakhin et al.,2001] (especially - in the monograph of Ilyin [Il'yin, 1995] and in publications edited by him [Il'yin et al., 1995]). Dose characteristics for the liquidators register (apart from VK Ivanov et al, 2004) periodically appear in the "Radiation and Risk" journal (Obninsk) [Collective work, 2009]. The Internet is accessible for on-line informative publication OV Belyakov which details all the above aspects of the liquidators at the end of 1990 [Belyakov et al., 2000]. More information is represented in the BEIR-VII [BEIR, 2006] although the epidemiology of the liquidators is stated there unconsistently in the way of final conclusions.

The essence of the term and the composition of the cohort. Firstly there existed a prevailing view that the consequences of the explosion at the Chernobyl nuclear power plant will soon be eliminated, hence the term "liquidators" appeared. Then it became clear that to eliminate totally all the consequences of the Chernobyl accident is impossible (we can only weaken) but the name "liquidators" remain unchanged and entered into all reports, publications and public documents [Il'yin, 1995; Il'yin et al., 1995].The term "liquidators " means the person who implemented various tasks in 1986-1989 as usual within 30-km zone around Chernobyl. Among them there were both civilians and a large portion (up to 40% [UNSCEAR, 2000d] of troops.

Size of the cohort. The number of liquidators depending on the source can vary from several hundred thousand to a million [Belyakov et al., 2000]. For example, in the western sources there appear phrases about the total number of liquidators in the 600 thousand or even 800 thousand [Belyakov et al., 2000; UNSCEAR, 2000d] of people. Both of these values according to Il'yin [Il'yin et al., 1995] are highly exaggerated. In general, we say that the real number of liquidators is not known exactly because of the large contingent of military liquidators, information about which has not been available for a long time [Il'yin et al., 1995]. As the most realistic estimates of the total cohort it was called the order of 300 thousand people [Il'yin et al., 1995]. At the same time in 1986-1987 (the most serious period) at the station and at the 30-kilometer zone around it worked about 230 thousand liquidators [Il'yin, 1995] according to LA Ilyin et al. WHO in 2006 numbered about 400 thousand people in a 30-kilometer zone for the period of 1986-1987. However, in the BEIR-VII USA (2006) for the same period there figured about 200 thousand people [BEIR, 2004]. It was established a universal State Register of exposed individuals of the USSR in Obninsk in 1986 which included not only the liquidators but also the evacuees and residents of contaminated areas. The Register existed until the end of 1991 and since 1992 due to the collapse of the Soviet Union it was replaced by national registers in Russia, Belarus, Ukraine and the Baltic States [Collective work, 2009].

Types of exposure. The liquidators were subjected to combined irradiation: total due to external γ-and β-radiation, contact β-γ-radiation exposed areas of the body and external irradiation with radionuclides. It is generally accepted that there had been, mostly, external radiation though it could not be discounted the domestic one, especially in the early period of work. It's possible to mention about the inhalation effects of so-called "hot particles" incorporated into the lungs (these particles are formed by the destruction of the reactor design). In addition to various metals and γ-emitting compounds (^{90}Sr, ^{137}Cs, etc.), the "hot particles" could densely include radionuclides, especially plutonium. It's also worth talking about the presence of "hot particles" in radioactive graphite reactor. These particles can have a high activity and create around themselves a high local radiation dose.

The contribution of internal exposure and estimated doses. In addition to external exposure and the significant effects of β-radiation to the skin the liquidators were also subjected to internal exposure of incorporated radionuclides and thyroid exposure due to inhalation of I^{131} and short-lived radioactive isotopes of iodine [Aleksakhin et al., 2001; Il'yin, 1995]. In the period from April 30 to May 7 in 1986 the dosimetry of thyroid (with bringing up the sensors to the head and neck) was performed in more than 600 liquidators. Estimates of doses to the thyroid gland (assuming the disposable income of I^{131} and the lack of stable iodine[17] prophylaxis) showed the following: 64% of the liquidators received doses of less than 0.15 Gy, 33% - in the range of 0,15-0,75 Gy, 2.5% - in the range of 0,75-1,5 Gy and the remaining 0,5% - in the range of 1,5-3,0 Gy. The average estimated thyroid doses - 0.21 Gy. The median value for the ratio of internal dose of thyroid to the external effective dose is estimated at 0.3 Gy to 1 Sv [Aleksakhin et al., 2001]. Internal dose from the intake of Cs^{134}, Cs^{137}, Sr^{90}, Pu^{239} and other radionuclides were determined in 326 liquidators surveyed from June 1986 to September 1987.

A considerable part of them - it's Chernobyl nuclear power plant personnel who participated in the liquidation of the consequences from the third to fourth day after the accident. Dose assessment was based on the measurement of γ-emitting radionuclides in the body for installation of WBC and the concentration of radionuclides in excreta. The expected value of the average effective dose (50 years) from the intakes of radionuclides was equal to 85 mSv [Il'yin, 1995]. Part of the effective dose, accumulated between June and September 1986, estimated as about 30 mSv. In 1987 and 1988 internal doses were much lower: for Cs^{134} + Cs^{137} - about 0,1-0,2 mSv per year [UNSCEAR, 2000d]. According to Meshkov (2009) the contribution of internal exposure to the total dose of 1986 varied in the range of 4,4-16%, depending on the work performed. In "fire period" (until May 6, 1986), the contribution of internal exposure were 10-20% and thereafter did not exceed 5%. There remained some critical group of early liquidators who had a probable higher level of internal exposure but this group does not exceed 2-3% of those working in that period.

Doses in liquidators and the possibility of induction of heritable genetic effects. Data for the retrospective biodosimetry and EPR dosimetry of tooth enamel which reflected the external and internal exposure are at least not too low compared with the official dosimetry. Nevertheless, even these data show that doses in the range of average (0,2-1 Gy [4, 64]) have gained hardly more than a third of the liquidators of the early period in 1986 (and the excess above the ground with small doses was very close to them in the range of 0,25-0,3 Gy). With regard to large doses (1 Gy [BEIR, 2006; Koterov, 2009]), they represented a negligible part of the cohort.

Let us remember the canonical value increment rate of hereditary effects over the background level for humans demonstrated in the previous section. It adds up to 0.54% at 1 Gy for all pathologies (Mendelian, multifactorial, and malformations). But even this estimate is too high. In ICRP 103 per sec.53 it shows the "standard" assessed risks, including hereditary genetic effects at 1 Sv [ICRP, 2006]. These values are also represented in the Russian NRB-99/2009. According to ICRP-103 the risk of hereditary effects of radiation from the background level compiles of 0.2% at 1 Sv for the total population (but only for an adult - even less) [ICRP, 2006].

5. Study of transgenerational mutation in the liquidators at the molecular genetic level did not reveal the effects of radiation exposure

In the direct determination of the frequency of mutation in the coding genes and determining the inherited disorders and abnormalities in the offspring have not been received a uniquely information about the presence of transgenerational effects of irradiation in human populations due to the inability of reaching the necessary quantities of samples (see above). Clearly, if the effect is induced with a frequency of 0,2-0,5% of the background level even for doses of 1 Gy, the epidemiology of small and medium doses would require an unrealistic size of the cohort. As a result, there began the search for other more sensitive methodological approaches which was realized in the study of mutations in minisatellite DNA in the 1990's. [Dubrova et al., 1996].

The main features of minisatellite applied to search for inherited effects of radiation are as follows [COMARE, 2002; BEIR, 2006; UNSCEAR, 2006a; ICRP, 2006; Dubrova et al., 1996; Jeffreys et al., 1997]:

- Selective neutrality (not removed by natural selection).
- High frequency of spontaneous mutagenesis in minisatellites loci, which is 1000 times greater than the rate for coding genes.
- The presence of mutations in some minisatellite germ cells of mammals.

A number of studies devoted to inherited mutations in the loci of mini-and microsatellite DNA in children of liquidators were provided. These studies were conducted entirely by foreign authors [Livshits L.A. et al. in 2001 (Ukraine-France), Slebos R.J. et al. in 2004 (USA), Furitsu F. et al. (Belarus-Japan), etc] or in cooperation with the staff of the CIS countries. No significant changes in the frequency of transgenerational mutation were identified.

6. Data on defects, anomalies and pathologies in children of liquidators in Russia, Ukraine and Belarus.

Despite the above theoretical and practical considerations that indicate a priority of the low probability of detection transgenerational effects of radiation on human cohorts, such studies are quite active. In recent years academic and medical institutions of the three countries of the CIS conducted various studies of children liquidators. As a result, these children have found violations, defects and diseases in all conceivable levels: molecular, biochemical, chromosome, immunologic, genetic, physiological, psychological, intelligent, mental. As far as we know, we still could not reveal the frequent release of a cancer but with such intensive research, it is probably only a matter of a time. Relevant data clearly can occur when children of the liquidators or their grandchildren will be included in the appropriate age.

Virtually, all effects of excessive violations, defects, and disease (often highly expressed) for the children of liquidators were found. And overall interpreted as an adverse genetic effects of radiation. Nevertheless, as we have said, totally denying the changes and violations does not seem to be advisable. But sometimes there declared something beyond all reasonable framework: that almost half of the children of liquidators has the profound abnormalities in all investigated parameter including the delays mental development and the cytogenetic damage.

It should be noted that we have not met the dependence of any effect on the dose of fathers-liquidators (with one exception - below) in any work. (in terms of miscarriage, CDF, etc.) in Russian study [Sipiagina et al., 2006a; Sipiagina et al., 2006b], but the dependence does not seem to be apparent there. In light of the fundamental conclusion that the transgenerational effects of radiation exposure is unlikely to detect, it seems implausible that the main factor inducing all those registered effects deal with the deviation and pathology, is radiation. There should be another causes, not related to radiation exposure. The following ones are the data on the effect of stresses from different nature. The induction of mutagenesis of the parents (who by germ cells can be transmitted to offspring) and directly at children is shown below.

7. Effect of neuro-emotional stress, mental disorders and abnormalities in genomic and chromosomal damage

Potential induction of cytogenetic damage with stress and mental disorders is the proven fact of formation in such situations the high concentrations of reactive oxygen species and lipid peroxidation products. Stress, in any kind and at almost any level of the organization alive, realized ultimately in an oxidative process. The emotional stress is no exception. The overwhelming majority of DNA damage due to any genotoxic effects caused not by any direct action as, for example, radiation, chemicals, and etc. but due to indirect effects generated by oxidation of compounds. The effect of free radicals takes place even in the case of mediation genotoxic and cytotoxic effects of stress hormones (sympathetic, etc.). Thus, there may be a probable chain of events: psychogenic stress → damage in DNA and chromosomes in sperm cells due to the oxidative stress → mutagenic disorders, anomalies and pathologies in the offspring.

Studies of people living under psychogenic stress. Psychogenic and neuro-emotional stress whether it is temporary, acquired or genetically determined (as suffering from some hereditary mental illness) is recorded at different levels of molecular and chromosomal organization of the genome. In the conditions of psychogenic stress there were revealed:

- Oxidation of DNA with the formation of violations of its structure;
- Elevated levels of DNA damage;
- Reduced ability to repair it;
- Reduced capacity for adaptive response to genotoxic effects;
- Increased sensitivity of the genome of cells to external influences;
- Damage of genes;
- Increased "fragility" of the chromosomes;
- Increased level of chromosomal aberrations;
- Increased levels of sister chromatid exchanges;

• Aneuploidy;
• Induction of apoptosis (which removes cells with damaged genomes).

In the review [Collodel et al., 2008; Gidron et al., 2006] it is critically reviewed several studies in which the correlation between psychological stress and DNA damage is represented in animal and clinic. The conclusion about the reality and reliability of such communication which particularly depends on age has taken place there. As a result, we can assume with high probability that if the liquidators while working at Chernobyl, shortly thereafter, or in disadvantaged socio-economic conditions of 1990 were in a state of acute or chronic emotional stress, it was inevitably reflected in a state genome of germ cells.

Next, let us consider the *immediate* data on how parents being in a state of stress may affect their offspring.

8. Effect of neuro-emotional stress and mental health of parents at induction of irregularities and abnormalities in their offspring

In the study of the offspring of people exposed to the adverse effects or being in a particular physiological or psycho-emotional state, it is important to choose the control cohort correctly. When searching for genomic and chromosomal abnormalities of the offspring, related defects and the CDF, we should take into account the contextual factors such as:

- The dependence of the genomic and chromosomal abnormalities in children based on the hysiological and pathological maternal factors, external influences on mothers (both before pregnancy and during it);
- Violations and pathology in children whose parents are in a state of stress and depression;
- Violations and pathology in children which pregnancy was not desirable.

9. The sensitivity to adverse factors during stress psychogenic nature

Psycho-emotional stress increases sensitivity to mutagenic factors such as chemical and physical nature. It is shown that the chronic psychogenic stress in human cells increases the sensitivity to the induction of DNA damage, while their ability to repair is reduced (the study of lymphocytes sensitized by irradiation or hydrogen peroxide in vitro). For the Russian studies [Liaginskaia et al., 2009] with their identified "dose" dependence, we can expect a significant epidemiological effect of preventing or «confounding » factors such as stress. Apart from the contagious effects, psycho-emotional stress can also be regarded as "mixing" factor, the effect of which can interact with the effects of other factors. As stated in the UNSCEAR 2000 to the combined action of radiation and other agents, the studied stressors can provide additive, synergistic and antagonistic effects on the CNS. [UNSCEAR, 2006a]. The stated arguments leads us to the important conclusion that children born from parents in a state of emotional stress such as depression should be more sensitive to the toxic and genotoxic factors in everyday life and in the environment. It is possible that this factor caused the identified in several studies genomic, chromosomal and cytologic abnormalities in children of liquidators. To sum it up, many effects can occur after birth and they have no relation to heritable genetic effects of radiation per se. But psychogenic stress is not the non-radiation factors faced by the liquidators. There was also a chemical stress, and some household effects. All this could affect the health of their offspring.

10. Hereditary non-radiative effects of factors that could affect the liquidators

There also existed a number of non-radiative factors that could reveal a rigorous consequences in liquidators health. They are:

- Heavy metals, particularly lead, which drowned the reactor and the effects of free compounds of the lead;
- Petrol fumes, fuels and lubricants;
- The effects caused by solvents and other organic compounds;
- Medications and drugs;
- Alcohol;
- Heavy smoking.

11. Psychogenic stress and psychological distress in liquidators

There are several studies that found increased frequency of psychogenic stress, anxiety and depressive disorders, asthenic-neurotic pathology, etc. abnormalities in liquidators. [Rahu et al.,2006; Bromet and Havenaar, 2007; Metlyaeva, 2009]. Post-traumatic stress disorders, including social functioning, are shown in the liquidators after 15-17 years after the Chernobyl accident. Similarly, 20 years after the accident revealed the stress caused by cognitive and psychological disorders. The frequency of depression, anxiety (especially as a symptom of posttraumatic stress) and unexplained from the perspective of traditional medicine physical and physiological disorders met more in 2-4 times compared to the control (the rate of diagnosed mental health pathology was not improved). Severe emotional stress cause the liquidators excess of suicides.

12. Conclusion

The purpose of this review was to determine the correctness of the findings on radiation effects, and pathological condition in children of liquidators of the Chernobyl accident.

Based on identified patterns of radiation genetics as reflected in the documents of international organizations (UNSCEAR, ICRP, BEIR, COMARE) and on the magnitude of doses accumulated by the liquidators, it was found out that the issue of registering the transgenerational effects of irradiation in the offspring of the liquidators with the available now methods and epidemiological approaches is remained problematic. On standardized global estimates of risk of inherited disorders and pathologies, the irradiation of parents even at a dose of 1 Gy (this is the boundary between the medium and high doses) leads to the estimated risk ranges from 0.2% to 0.54% above the background levels of indicator. According to the most inflated estimates of biodosimetry, the accumulated dose of at least 2 / 3 of the cases did not come from a range of small doses (up to 0,1-0,2 Gy) even for the liquidators in 1986; as concerned large doses (to 1 Gy and above), only the tiny part of the liquidators was irradiated.

The identification of the growth of hereditary abnormalities and pathologies above the background is hardly probable and can be expected in any real sample of the offspring of liquidators, since, according to calculations, there requires a large cohort numbering many tens - hundreds of thousands of children to identify any effects. But the total cohort of the offspring of liquidators in Russia has only about 39.000 people, and for a joint Russian-Belarusian register of the offspring of liquidators, we have about 50.000.

Mismatches of the data on children of liquidators with the laws and the "standard" risk of hereditary effects adjusted by the world of radiation genetics are raises the problem of radiation attributiveness declared effects. This conclusion is confirmed by the study of transgenerational effects of the liquidators at the molecular genetic level: in five international research on the offspring of the liquidators it was impossible to detect the reliable increase in the frequency of heritable mutation, even in the repeats of minisatellite DNA mutation rate which is greater in 1000 times than the rate for coding genes (responsible for hereditary abnormalities pathology, CDF, etc.).

Nevertheless, the effects were found at different levels in children of liquidators. In recent years (maximum in fifteen years) in Russian academic and medical institutions Russia (9 groups of authors), Ukraine (9 groups of authors) and Belarus (2 groups of authors) there conducted studies of children of the liquidators. As a result there were found different violations, defects and pathology at all conceivable levels: molecular, biochemical, chromosomal, genetic, immunological, physiological, psychological, intellectual and mental. In this paper we have presented an extensive summary of relevant publications. Not all of them are peer-reviewed and presented in some refereed journals. Nevertheless, even in the light of the low probability of registering the transgenerational effects of radiation in humans, it seems to be inappropriate to deny the fact of increased frequency of several disorders, anomalies and pathologies in two dozen studies from Russia, Ukraine and Belarus in children of liquidators. On the one hand, we cannot agree with the fact that almost all the original sources of the detected anomalies and diseases are hereditary effects of exposure of their fathers. Radiation laws of human genetics are not allow to consider such conclusions as the correct ones. On the other hand, if we reject the possibility of artifacts, the effect of screening, the errors and tendentious exaggeration encountered in some studies, there arises a question about the real non-radiation risk factors, which are registered and could influence the liquidators health (or children of liquidators) or caused the adverse effects.

As a result, one of us and co-workers back to 2001 [Biryukov et al., 2001; Gabidulina, 2001] concluded that the multicomponent effect of adverse factors in the children of liquidators, among which were the main non-radiation factors: stress, strain diets, restrictions regime, and etc. , *"not associated with a dose of radiation received by parents in emergency response but with their socio-economic failure in today's society"* (at the same time a part of the radiation factor in a number of metabolic disorders is not completely excluded).

Finally, the liquidators had direct exposure times of a specific set of non-radiation factors, such as "hot particles, heavy metals (lead), gasoline or diesel fuel, coupled with the exhaust gases (gasoline contains benzene that reflected in the progeny), organic compounds, drugs, alcohol, inveterate smoking and etc. Of course, individually, these factors are not something unique but they formed a complex that could be specific just for the liquidators.

Thus, it seems that the identified violations, defects, pathology in the children of liquidators are inexplicable in light of the accumulated data of radiation genetics and radiation epidemiology due to complex non-radiation factors, the predominant of which is the psychogenic stress. That psychogenic stress may cause subsequent psychological formation and the related adverse lifestyle (which will further contribute to the effects) unfavorable both for the individual and for his family and the offspring.

We can assume that if the liquidators and their families would have been properly informed from the outset about what really can be expected to them and their offspring, under the doses that they have accumulated, the majority of cases of psychogenic stress, related disorders and the subsequent negative lifestyle could have been avoided. This regards to all other consequences and the effects for both individual and family.

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