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OPINION

On protecting the inexperienced reader from Chernobyl myths

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Abstract

The health and environmental consequences of the Chernobyl accident continue to attract the attention of experts, decision-makers and the general public, and now these consequences have been given added relevance by the similar accident in 2011 at the Fukushima-1 nuclear power plant (NPP) in Japan. Expert analysis of radiation levels and effects has been conducted by international bodies—UNSCEAR in 2008 and the Chernobyl Forum during 2003–5. At the same time, three Russian and Belarusian scientists, Yablokov, Nesterenko and Nesterenko (2009 *Chernobyl. Consequences of the Catastrophe for People and the Environment* (New York: Annals of the New York Academy of Sciences)) published both in Russian and English a substantial review of the consequences of Chernobyl based mostly on Russian-language papers. In this book, they suggested a departure from analytical epidemiological studies in favour of ecological ones. This erroneous approach resulted in the overestimation of the number of accident victims by more than 800 000 deaths during 1987–2004. This paper investigates the mistakes in methodology made by Yablokov *et al* and concludes that these errors led to a clear exaggeration of radiation-induced health effects. Should similar mistakes be made following the 2011 accident at Fukushima-1 NPP this could lead quite unnecessarily to a panic reaction by the public about possible health effects and to erroneous decisions by the authorities in Japan.

1. Introduction

The publication by the New York Academy of Sciences of the book by Yablokov, Nesterenko and Nesterenko (plus Consulting Editor, Janette D Sherman-Nevinger) entitled *Chernobyl: Consequences of the Catastrophe for the Population and the Environment* (Yablokov *et al*

2009) is, quite frankly, not conducive to increasing confidence in the work of the Academy. The book was prepared by three scientists from Russia (AVY) and Belarus (VBN and AVN), and is mainly based on Russian-language publications on the consequences of the Chernobyl accident for human health and the environment. Unfortunately, the authors did not make any effort to analyse critically the content of these publications, and to separate them into those that contain scientific evidence and those based on hasty impressions and speculative conclusions. Therefore, the main conclusions of Yablokov *et al* (2009) are an odd mixture of established facts (e.g. increased thyroid cancer in children in the areas of Belarus, Russia and Ukraine heavily contaminated with radionuclides) and uncorroborated claims of mass mortality in emergency and recovery operation workers ('liquidators'), of abnormalities in newborns, and a host of other supposed effects of radiation. An inexperienced reader will have difficulty in separating the firm from the unsubstantiated conclusions, and the present paper is intended to assist him/her in doing so.

The earlier version of this book was published in 2007 in Russian under the aegis of two non-governmental organisations, Greenpeace and Bellona (Yablokov *et al* 2007). The list of cited references in both versions indicates that the authors curiously avoided the most generally cited Russian-language papers, which received serious international peer review and were published in respected journals. These hundreds of journal papers by authors from Russia, Belarus and Ukraine were analysed in detail by teams of independent international experts and became the basis for the comprehensive work of the UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (UNSCEAR 1988, 2000, 2008a) and the UN Chernobyl Forum (IAEA 2006, WHO 2006, UNDP and UNICEF 2002, Chernobyl Forum 2006). Careful analysis of previously published peer-reviewed papers, with the final separation of grain from the chaff, is the key to the objectivity of the findings of these international bodies.

As already noted by Jargin (2010) and Jackson (2011), Yablokov and his co-authors give extensive references to the media, commercial publications, websites of public organisations or even unidentified ones, to justify their ideas. These are also the sources for statistical data on demography, morbidity, etc., which are not considered seriously by the scientific community for the very good reason of dubious reliability. Most of the references are conference proceedings, abstracts of theses and brochures in Russian, largely unknown to the world and hardly accessible even in the former Soviet Union, not to mention the rest of the world. Thus, independent verification or clarification of the data presented by the authors is virtually impossible.

It is difficult for me to remain impartial in considering the contents of this book as I was scientific secretary of the UN Chernobyl Forum and a key consultant to UNSCEAR in the preparation of its recent report on Chernobyl (UNSCEAR 2008a). The book by Yablokov *et al* (2009) is full of doubtful claims of 'new methodology' research, and contains numerous factual errors, so that the desire to accord the authors the 'benefit of the doubt' becomes a secondary issue compared with the urgent need to defend the scientific evidence on the effects of Chernobyl.

Since 2011, this subject has again became especially topical because of the nuclear accident at Fukushima Daiichi nuclear power plant (NPP). Whereas radiation conditions in some affected areas of Japan are in many respects similar to those in the former USSR following the Chernobyl accident, a comparison inevitably comes to mind regarding health consequences. The groundless exaggeration of the health effects of Chernobyl by Yablokov *et al* (2009) demands a robust response in order to avoid panic in the public and erroneous decisions by the authorities in Japan.

Let me try to briefly consider the main findings of Yablokov *et al* (2009) in its respective chapters.

2. Chernobyl contamination

Chapter I of the book provides an overview of the known data about the deposition of Chernobyl radionuclides in the countries of Europe and, to a lesser extent, in other parts of the world. Over the decade following the accident specialists have conducted millions of measurements on the ground and analyses of soil samples. These findings have been summarised by experts from the European Union and the former Soviet Union, which culminated in the release in 1998 of the well-known *European Atlas of Caesium Deposition after the Chernobyl Accident* (De Cort *et al* 1998). At this point, previous discussions among dosimetry experts on the levels of Chernobyl fallout mostly subsided.

However, the authors of the book have found a pretext for a confrontation with the radiological protection community. For obscure reasons, they continue to defend the idea that Belarus, Russia and Ukraine received less than half of the Chernobyl radioactive fallout, citing for this early model estimates from 1987–88, whereas it is now well established from data input to the Atlas of 1998 that those three countries received more than 70% of the activity of caesium-137 from the total fallout in Europe (De Cort *et al* 1998). Outside Europe the amount of radioactive fallout was so insignificant that from a radiological protection point of view it may be virtually neglected.

The same chapter mentions an early dose assessment, a rather conservative estimate made by UNSCEAR of the collective effective dose for the entire world population from the Chernobyl fallout, which was equal to 600 000 man-Sv (UNSCEAR 1988). Recently, UNSCEAR published an updated, more accurate estimation of collective effective dose, based on radiological monitoring data over two decades (UNSCEAR 2008a). For the population of Belarus, the European part of Russia and Ukraine, the current estimate is 125 000 man-Sv, and for the rest of Europe, 130 000 man-Sv, for 1986–2005. Over 20 years, the population received 80% of the total dose from Chernobyl fallout; the total expected dose in Europe is estimated as 320 000 man-Sv. Accordingly, the assessment of the full post-factum global dose is about 400 000 man-Sv, that is only two-thirds of the initial estimate by UNSCEAR.

As for the three countries of the former USSR, to the 156 000 man-Sv of total expected collective effective dose (125 000/0.8) one should add another 59 000 man-Sv received by emergency and recovery operation workers in these countries in 1986–90. This will give a total of 215 000 man-Sv, which is somewhat higher than in the rest of Europe ($130\,000/0.8 \approx 160\,000$ man-Sv)—a point with which the authors do not agree for some reason.

3. Consequences of the Chernobyl catastrophe for public health

The central chapter of the book (chapter II, sections 2–7, 190 pages, author Yablokov) is entirely devoted to the health consequences of the Chernobyl accident.

3.1. The methodology

The most impressive part is section 2, on methodology. It begins with the author's reasonable reproach against the Soviet authorities on the classification of data during the first years after the accident, as well as the unreliability of official health statistics. The author points out the lack of direct measurements, particularly for individual dosimetry, which makes the reconstruction of doses received by epidemiological study subjects quite complicated. In the professional community, this fact required the development of special models of dose reconstruction based on both external and internal exposure data which were later successfully applied in post-Chernobyl radiation epidemiological studies. However, Yablokov draws the unexpected conclusion that since dosimetry information is 'unavailable', the classic epidemiological dose–response requirement simply does not apply.

Further, Yablokov insists on changing the currently preferred radio-epidemiological methodology and rejects the findings of analytical studies (cohort, case–control) because they require the reconstruction of individual doses—the method that he does not trust. Instead, he proposes the use of so-called ecological or geographic methodologies, in which health indicators averaged over areas with similar environmental, social and economic conditions, but with different levels of radioactivity, are compared. However, international experience in radiation epidemiology (UNSCEAR 2000, 2008a) has repeatedly demonstrated that this approach can lead to erroneous conclusions (the so-called 'ecological fallacy'), and the book demonstrates this once again.

The Chernobyl accident became a major problem for the former Soviet Union and its successor countries. In particular, both the general population and health workers became overly alert with regard to possible radiogenic diseases. Not surprisingly, many medical research institutions and individuals have vigorously studied the incidence and mortality of Chernobyl-affected populations, trying to find any changes that may be, quite naively, attributed to Chernobyl radiation. The most accessible analysis—according to Yablokov's recommendation—is a simple comparison of medical and demographic indicators between areas contaminated with radionuclides and so-called 'clean' areas, and also between the liquidators and the rest of the population. It is known, however, that health screening and diagnostic techniques are not well harmonised, and the incidence of the same disease in different geographic areas reflects not only the actual health of residents, but also the diagnostic capabilities of local doctors. Therefore, a geographic comparison of the officially reported incidence rates is not at all a suitable indicator to detect the subtle effects of such risk factors as radiation.

The second proposal by Yablokov—to observe the changes in health indicators over time and relate them to the amount of radiation—is also very popular among non-professionals. However, in the late 1980s and especially in the 1990s, enormous socio-economic changes took place in the countries of the former USSR and led to a serious decline of the health care system and to increased morbidity and mortality. To identify radiogenic effects over this pronounced background of health effects is a complex scientific task that cannot be solved by simple methods of comparison of past and current health indicators. This severe problem is illustrated by the study of Men *et al* (2003) of mortality trends in Russia during 1991–2001. They showed that in contrast to the steady decline of standardised mortality rates in Finland and the Czech Republic, the rates in all regions of Russia rose markedly to a peak in 1994, and then to another peak in 2001—if anything, the effect was greatest in the far east of Russia that was hardly affected by the Chernobyl accident. These dramatic patterns of background mortality in Russia continued into the first decade of the 21st century (Zaridze *et al* 2009). To think that geographic studies can segregate any Chernobyl effect from such a background is illusory.

Radiation is a relatively weak carcinogen, and its health effects in the population are identified with great difficulty and only with internationally recognised analytical techniques taking individual account of not only the dose but also of other factors influencing the risk. The only exception was the post-Chernobyl radiogenic thyroid cancer in children because the doses from radioiodine were so high (up to tens of gray), the number of children receiving high thyroid doses so large, and the spontaneous incidence rate in children is so low (a few cases per million population per year) that the effect of radiation was detected both in analytical and ecological studies (UNSCEAR 2008a).

The shortcoming of an ecological approach in epidemiology is the strong influence of the screening effect, i.e. different levels of medical diagnosis and treatment accessibility that will vary with radiation levels across the study area. The awareness of doctors in the areas known as contaminated, and specially allocated resources for medical examination and screening of the affected populations and clean-up workers, will quite expectedly result in a much larger number of diagnoses of both somatic and psychogenic diseases. In particular, for this reason it is inappropriate to compare health data indicators for a vigorously surveyed population (e.g. Chernobyl liquidators) with the data for a population of non-contaminated areas or the whole of the Russian population—and this is exactly what Yablokov is trying to do. The screening effect has its strongest bias for studies identifying radiation-induced health effects. A tool to overcome the screening effect is known: it is the dose–effect analysis within a cohort of people who underwent the same rate of screening—the very approach rejected by Yablokov.

In fact, the denial of the analytical approach and the unconditional trust in the ecological or geographic methodology with primitive statistical tests puts an end to the credibility of any conclusions in chapter II. Nevertheless, here is a brief discussion of this material.

3.2. Low-dose effects

Sections 3–5 of chapter II contain a lot of material about the different effects of low doses of radiation: the overall morbidity of the population and its accelerated ageing, benign and malignant somatic diseases, diseases of the endocrine, immune, respiratory and genito-urinary system, diseases of the musculoskeletal system, digestive system and other internal organs, skin and teeth, infectious and parasitic diseases, diseases of the nervous system and sensory organs, mental health problems, genetic changes in germ and somatic cells, congenital malformations, diseases of children of 'exposed' parents, etc. Section 6 is largely devoted to cancer morbidity. Section 7 examines the post-Chernobyl mortality of liquidators and populations living in the areas of radioactive contamination.

Each section and subsection is structured into the three countries of the former USSR and 'other' countries, and has numerous (tens or hundreds) of references, usually Russian-language works. Quite naturally, researchers chose to study the people who have received the highest doses of radiation, i.e. liquidators and the population of the most contaminated regions in Belarus, Russia and Ukraine. The authors of the book disagree with this simple approach, but they are actually forced to follow the same path. Some articles/abstracts contradict each other, but mainly it those that paint an alarming picture that are selected for discussion. Each section ends with conclusions about the catastrophic effect of Chernobyl radiation on human health, including increasing death rates.

As noted above, the whole of chapter II has a format of a refereed journal, which systematically presents summaries of many articles without any attempt to analyse methodology, rather than results. Selection of articles and Yablokov's conclusions appear to be predetermined by his belief in a totally and widespread negative effect of any dose of radiation, and he is not in the least embarrassed by stark contradictions between the findings of the selected works and his own conclusions, and with a century-long experience of radiobiology and radiation medicine. It is a dark irony that Yablokov has expressed a reasonable distrust in domestic medical statistics but he fully trusts them when they lead to a frightening conclusion about radiation effects on health. The value of such a review is not just zero, but negative, as its lack of balance may only be obvious to specialists, while inexperienced readers may well be misled.

Describing 'radiogenic' mortality, Yablokov seems to forget that we are all mortal, including liquidators and the population of the contaminated areas, and attributes mortality mainly to radiation. Meanwhile, the quite accurate data of the Russian national registry shows that mortality rates of liquidators standardised by age and sex are no higher, but even lower than those of the general population of Russia (Ivanov *et al* 2004). Yablokov's estimation of population mortality due to Chernobyl fallout of about one million before 2004 (section 7.7) transports this book from science to the realm of science fiction. Clearly, if such a mass death of people had occurred as a consequence of Chernobyl, this would never have passed unnoticed. Moreover, there is the point not so much about the population of the three countries as of other European countries, and even countries outside Europe.

Why am I so sceptical towards Yablokov's conclusions about the catastrophic effect of Chernobyl radiation on human health? There are mainly methodological grounds for it. A key postulate of modern radiation epidemiology, requiring proof of a radiation dose–effect relationship, is summarily rejected; selection of articles is unbalanced; articles where the effect of radiation is not found are ignored; Russian-language works (by Ivanov and others) where the authors are carefully looking for effects of radiation using modern epidemiological methods (sometimes they are found, and sometimes not) are neglected; and much more (see above).

3.3. International assessment

The work reported in the book is drastically different from the work of international scientific bodies such as UNSCEAR and the UN Chernobyl Forum. Firstly, these bodies involve dozens of the world's best specialists in radiation epidemiology, and the discussion and decision-making is collective, until a consensus is reached. Secondly, only those works which passed through serious international reviewing and are published in reputable journals, preferably international ones, are being considered. Works of another class (theses, abstracts, etc), which Yablokov refers to, are excluded from consideration by these international bodies as they do not meet the necessary qualification requirements. Thirdly, the focus is on research methodology, which should correspond to the current approach of epidemiology: only results of methodically proper studies are taken into account. Finally, if the results of a study seriously contradict present knowledge, the authors of the work are often asked to continue to clarify their findings and resubmit their results.

Such strict procedures of data consideration guarantee the validity of scientific conclusions. That is why reports from UNSCEAR are the most authoritative source of current knowledge on radiation effects, some sort of 'bible of radiation medicine'.

It is important to note the difference of initial positions of epidemiology experts from the position of Yablokov: experts are looking for identification of at least minimum demonstrable effects of radiation on the population and liquidators in order to clarify the radiation risk coefficients for radiation protection purposes. They have not really been successful so far, with the exception of the cases of thyroid cancer in children and leukaemia in workers (the latter to be confirmed). Mass radiogenic morbidity and especially mortality of the public or liquidators is not the question. This has not been revealed over 25 years of intensive medical and demographic research, and is not expected in the future. However, Yablokov is still seeking to convince the public of the mass impact of Chernobyl radiation on the population. These positions are fundamentally incompatible.

4. Consequences of the Chernobyl catastrophe for the environment

This less socially hot topic of the effects of Chernobyl on the environment is dealt with in chapter III. Data on the content of radionuclides in biota listed in section 8 do not cause much objection. Section 9 provides data on the radiobiological effects on plants, mainly in the exclusion zone in the early years after the accident. After the end of the period of acute exposure and death of plants near the reactor, many radiogenic somatic and genetic alterations were confirmed by experimental studies. With the lapse of time and due to the decrease of radiation levels in the exclusion zone, the frequency of the observed radiobiological effects gradually decreased and most of them were eliminated (IAEA 2006, UNSCEAR 2008b).

Similar patterns were observed with regard to fauna (section 10). The difference is that the restoration of the strength, health and biological diversity of fauna that resided in the exclusion zone following acute exposure supposedly took place by means of both biological mechanisms at the local level (repair, repopulation) and by immigration of individuals from surrounding areas, especially after the removal of people. The contribution of these fundamentally different processes is yet to be evaluated (IAEA 2006, UNSCEAR 2008b).

5. Radiation protection after the Chernobyl catastrophe

Sections 12–15 of chapter IV discuss some issues of radiation protection of the population after the Chernobyl accident, mainly on the case study of Belarus, where two authors, V B Nesterenko and A V Nesterenko, actively worked. Section 12 provides monitoring data for radionuclides in food as well as in the bodies of the residents of Belarus and does not raise particular objection.

More controversial is the material in section 13, which is dedicated to the reduction of the content of radionuclides in residents of the contaminated areas of Belarus. For decorporation of caesium-137, which represents the main post-Chernobyl problem, the successful application of ferrocene and other forms of Prussian Blue is known (Gusev *et al* 2001). However, it is used only in cases of emergency following the intake of large activities in the human body both under occupational and communal conditions (IAEA 1988), or it is given as a protective drug to cattle to clean milk and, less so, meat from radiocaesium (IAEA 1994). Prussian Blue is not used in cases of chronic radionuclide intake that causes low internal radiation doses.

Under these conditions, under which the major part of the Belarusian population lives after the Chernobyl accident, the authors tested pectin medicines and recommended them for widespread use in order to reduce the radionuclide content in children (Hill *et al* 2007). There is clearly a lack in the optimisation procedure of this radiation protection measure (ICRP 2006) with evaluation of the benefits of the drug (reducing radiation risk) and possible damage to health (was this drug ever tested for prolonged use?), the cost of the measure and its perception by the population. The result of the optimisation analysis is not obvious under low doses of internal radiation and even smaller averted doses.

Section 14 describes radiation protection measures related to agriculture, forestry, hunting, fishing and everyday life. Many of the recommended measures are quite common in the three countries following the accident (Alexakhin *et al* 2004, IAEA 1994, 2006). However, it is questionable advice to eat foods rich in potassium and calcium, and to drink plenty of fluids to reduce the incorporation of caesium-137 and strontium-90. I worked for many years in this field of science, and I am not aware of any works where the effectiveness of these methods has been shown experimentally. Inexperienced readers should be protected against these unconfirmed recommendations.

A statement on increasing levels of internal exposure of the public since 1994 contradicts the general trend of monitoring data in Russia; on the contrary, levels are gradually decreasing with the half-life of 10–20 years (IAEA 2006). As opposed to the opinions of the authors, international experts have shown that the formation of americium-241 (from the decay of plutonium-241) in the environment does not amount to a serious radiological problem (IAEA 2006, UNSCEAR 2008a). From the standpoint of modern radiation protection there is hardly a need for countermeasures to be kept longer than a few decades (the authors write about centuries), and the area where they will be justified will gradually reduce in size.

The final section 15 summarises the views of the authors on the effects of the Chernobyl accident and measures to address them further. Once again a fundamental ignorance is shown in the approach to the assessment of health impacts and the explicit neglect of the achievements of radiation epidemiology in the 20th century. Accordingly, the implications of the accident are repeatedly overestimated (see also Jargin 2010) both regarding the list of radiation-caused diseases and the number of accident victims (more than 800 000 for the period 1987–2004). They predict a growth in the number of victims for a few generations hence (section 15.4), but this is not justified by objective data.

Among the measures recommended by the authors to reduce internal exposure, some relating to agriculture and forestry are quite reasonable. But the authors, who do not have the appropriate expertise, should refrain from giving any advice of a medical nature on decorporation of radionuclides by ample drinking, etc, as well as on so-called 'reducing the morbidity' and genetic counselling.

6. Summary and conclusions

The Chernobyl accident was the largest nuclear disaster ever, which has led to numerous harmful effects on the environment, public health and social life. The professional scientific community is patiently and carefully examining the aftermath, and drawing lessons from what has happened. There are no reasonable grounds to suspect the modern community of experts of concealment of the facts. Conversely, professional epidemiologists are searching for positive scientific findings, and a proved radiation effect is the most desired scientific outcome for them.

Intervention by inexperienced investigators (although having impressive academic titles) in this delicate process, and publication of their 'findings' in the popular scientific press, prevents informed public understanding and decision-making by those authorities responsible for protecting the population. In particular, critical analyses of the book by Yablokov *et al* (2009) by a number of experts (e.g. Jargin 2010, Jackson 2011) and in the present paper should help to assist in the neutralisation of its adverse effects on the Japanese public and authorities following the Fukushima Daiichi NPP accident.

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