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Book Reviews

Information resulting from studies of the aftermath of the Chernobyl disaster is important to our understanding of radiation effects. A recently-published book entitled "Chernobyl: Consequences of the catastrophe for people and the environment", contains translations from the Russian of a series of papers on the subject written in 2007. Two expert reviewers, Dr. Ian Fairlie and Dr. Monty Charles, have herein provided their insights regarding this publication.

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CHERNOBYL: CONSEQUENCES OF THE CATASTROPHE FOR PEOPLE AND THE ENVIRONMENT

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On 26 April 1986, reactor 4 at the Chernobyl Nuclear power plant exploded, triggering a graphite fire that lasted for 10 d. The intense conflagration ejected large quantities of radionuclides into the atmosphere that were distributed by prevailing weather patterns throughout Europe and the rest of the Northern Hemisphere. The International Atomic Energy Agency[(1)] (IAEA) stated that Chernobyl was 'the foremost nuclear catastrophe in human history'. The IAEA and World Health Organisation[(2)] (WHO) stated that 'the magnitude and scope of the disaster, the size of the affected population and the long-term consequences make it, by far, the worst industrial disaster on record'. According to the International Programme on the Health Effects of the Chernobyl Accident[(3)] (IPHECA), the radioactivity released at Chernobyl in becquerel terms was 200 times that from the Hiroshima and Nagasaki atomic bombs combined.

Alexey Yablokov, founder and president of the Centre for Russian Environmental Policy, is a correspondent member of the Russian Academy of Sciences, and former environmental advisor to Gorbachev and Yeltsin. Vassily Nesterenko was director of Ukraine's nuclear power establishment in the 1980s and 1990s. In August 2009, he died mainly as a result of his radiation exposures from the Chernobyl reactor, but earlier he established the independent Belarussian Institute of Radiation Safety (BELRAD). Alexey Nesterenko is the Institute's senior scientist. The book under review here was translated by Janette Sherman-Nevinger, Adjunct Professor at the Environmental Institute of Western Michigan University.

The authors summarise studies demonstrating health effects in humans, animals and plants exposed to Chernobyl fallout over eastern and western Europe and the rest of the Northern Hemisphere. Their main conclusions are that the health and environmental consequences of the Chernobyl disaster are much larger than previously estimated. Exposures to affected people are reported to be increasing from the ingestion of contaminated foodstuffs whose ^{137}Cs concentrations are rising due to soil recirculation. The authors state that, collectively, the studies suggest that those exposed to low levels of radioactivity in the environment have higher risks than those estimated by western dose models.

Chapter I on the distribution of Chernobyl's fallout states that, although Belarus, Ukraine and Russia were the most highly contaminated countries, in fact western Europe received more than half of Chernobyl's fallout, and accounted for two-thirds of Chernobyl's collective dose to the Northern Hemisphere. The authors remark that IAEA and

WHO reports have failed to consider Chernobyl's health effects in western European countries. Chernobyl's fallout was spread over 40 % of the land area of western Europe and also over parts of Asia, northern Africa and North America. In Belarus, Ukraine and Russia, nearly 400 million people lived in areas contaminated with radioactivity at levels higher than 4 kBq m^{-2}—the lowest level for official acknowledgement. Nearly 5 million people still live in areas with very high levels of radioactive contamination, i.e. >40 kBq m^{-2} in Belarus (18 000 km^2), Ukraine (12 000 km^2) and European Russia (16 000 km^2).

Chapter II on health consequences states that due to USSR secrecy, data concerning thousands of Chernobyl cleanup workers are difficult to reconstruct. Due to the failure of nuclear 'technocrats' (a term used by the authors) to collect data on the number and distribution of the main radionuclides released, and the restrictions placed on physicians naming any medical findings radiation related, only 1 % of illnesses/injuries were so reported. The chapter states that reported adverse effects continue to increase in Belarus, Ukraine and Russia. Comparisons of morbidity/mortality in areas with low and high radioactive contamination reveal significant chromosomal abnormalities, marked increases in general morbidity, increased numbers of sick and weak newborns and apparent accelerated ageing. As regards non-malignant effects, studies among populations exposed to Chernobyl fallout have found increased incidences of brain damage; premature eye cataracts; tooth and mouth abnormalities; blood, lymphatic, heart, lung, gastrointestinal, urologic, bone and skin diseases; thyroid disease (with ~1000 cases of thyroid dysfunction for every thyroid cancer); genetic damage and birth defects in the children of liquidators and those born in areas with high levels of radioactive contamination; immunological abnormalities and increases in viral, bacterial and parasitic diseases in heavily contaminated areas. However, information on doses is limited. Official estimates by international agencies predict 9000–28 000 fatal cancers between 1986 and 2056. On the basis of predicted ^{131}I and ^{137}Cs doses, the chapter estimates 212 000–245 000 deaths in Europe and 19 000 in the rest of the world.

These are much higher than IAEA estimates: the main reason is that the authors' estimates include collective doses from very low exposures. The International Commission on Radiological Protection (ICRP) does not recommend including collective doses from low exposures; however, this practice is soundly based on the linear no threshold hypothesis for radiation's dose–effect relationship. The ICRP and most radiation protection agencies around the world continue to support the Linear No Threshold Theory (LNT) and routinely use it in estimating radiation effects. Therefore, the ICRP is being inconsistent when it says collective doses from very low exposures should not be used to estimate the effects.

Chapter III on the environmental effects states that Chernobyl radionuclides have concentrated in sediments, water, plants and animals, at up to 100 000 times higher than background levels. Despite downward vertical migration of various radionuclides in floodplains, lowland moors and peat bogs, plant root systems transport them back to the surface. This transfer is one cause of the increased ingestion radiation doses to people in contaminated territories observed in recent years. Radionuclide accumulation rates in plants and mushrooms depend upon soil, climate, particular biosphere, season, the particular species and subspecies. Radionuclides have very different plant accumulation rates (e.g. $^{90}Sr \gg {}^{137}Cs \ll {}^{144}Ce$), making it difficult to predict plant levels. Genetic disorders, structural anomalies and tumour-like changes have occurred in many plant species including unique pathologic complexes in the Chernobyl zone, such as high percentages of anomalous pollen grains and spores. Chernobyl radiation appears to have awakened genes silent over long evolutionary timeframes. Chernobyl radiation has resulted in morphologic, physiologic and genetic disorders in every animal species studied. Reports of a 'healthy' environment near Chernobyl for rare species of birds/mammals are the result of immigration and not local sustained populations. In 2009, contamination levels remain dangerously high for mammals, birds, amphibians and fish in many areas of Europe. Mutation rates in animal populations are significantly higher in contaminated than in non-contaminated areas: transgenerational genomic instability is seen in animal populations. Long-term observations of animal populations in heavily contaminated areas show significant increases in morbidity and mortality similar to those seen in humans—increased incidences of cancer and immunodeficiency, decreased life expectancy, early ageing and congenital malformations. Organisms such as tuberculosis bacilli; hepatitis, herpes and tobacco mosaic viruses; cytomegalovirus and soil micromycetes and bacteria underwent rapid changes in heavily contaminated areas.

Chapter IV on the continuing consequences states that food contamination from Chernobyl remains a major problem. As of 2007 in the Gomel, Mogilev and Brest provinces of Belarus, 8 % of milk and 16 % of other food products from small farms exceeded the permissible ^{137}Cs levels. As of 2000, up to 90 % of berries and mushrooms exceeded the permissible ^{137}Cs levels in the Rovno and Zhytomir provinces of Ukraine. From 1995 to 2007, up to 90 % of children in heavily contaminated territories of Belarus had ^{137}Cs levels higher than 15–20 Bq kg^{-1}—the action level recommended by BELRAD. Worryingly, the

average body ^{137}Cs and ^{90}Sr levels in heavily contaminated territories of Belarus, Ukraine and European Russia have been increasing since 1991. The result is that individual radiation doses in the contaminated territories of Belarus, Ukraine and Russia have also been increasing steadily since 1994. In 2008, the average dose in heavily contaminated territories of Belarus, Ukraine and European Russia exceeded 1 mSv y^{-1}—primarily from eating locally contaminated food. However, the administration of apple-pectin food additives is considered helpful for body decontamination of ^{137}Cs. Between 1996 and 2007, 160 000 Belarussian children received pectin food additives for 18–25 d: ^{137}Cs levels decreased by 30–40 %. Special protective measures in connection with agriculture, forestry, hunting and fishing will be necessary to protect the health of people in radioactively contaminated territories for many generations.

Ever since the Chernobyl accident occurred, its effects have been the subject of polarised views with claims and counterclaims on the scale of adverse effects especially on the estimated numbers of resulting deaths. The volume lists many major reports which have been published (in English) in western European countries and in eastern European countries (in Russian or Ukrainian): about a dozen major reports were published around the twentieth anniversary of the accident in April 2006. Reports by the IAEA and WHO differ markedly in their approach, contents and conclusions to independent and some national Government reports. For example, IAEA and WHO reports (especially the Chernobyl Forum reports[2, 4] in 2005) based their findings mainly on research published in the west and referred to relatively few of the thousands of research papers published in eastern Europe.

From this volume, many eastern European scientists evidently consider that the IAEA and WHO fail to acknowledge the scale of Chernobyl's effects and refuse to accept that radiation exposures from Chernobyl's fallout are the prime cause. The IAEA often seeks to justify their dismissal of eastern European reports on Chernobyl by disparaging eastern scientific protocols. This is an important issue which is repeatedly referred to by the authors and as these matters are rarely discussed in refereed journals, this reviewer examines them below.

For example, the IAEA/WHO[2, 4] have cited *questionable scientific practices* in eastern epidemiological studies, such as poor case identification, non-uniform registration, variable or uncertain diagnostic criteria and uncertainties in the uniformity of data collation. But to be fair, epidemiology is not an exact science and many of these methodological shortcomings exist, at least to some extent, in western epidemiological studies uncriticised by the IAEA. For example, studies[5, 6] by independent scientists have shown surprising lapses of standards in officially sponsored epidemiology studies in the West. As for cancer registries, not many western European countries had excellent detailed cancer registries in 1986.

The IAEA/WHO[2, 4] have also stated that excess mortality or morbidity may be uncertain due to *confounding factors, competing causes and different risk projection* models. This may be correct, but it is often the case in western studies as well. Of course, two wrongs do not make a right, but it is unfair to single out eastern reports in this regard. However, one major difficulty in interpreting Chernobyl mortality studies is the large recent decrease in average male life spans in Belarus, Russia and Ukraine in all areas not just contaminated ones: this deserves more attention in eastern studies.

It is a common practice in the West to test the findings of epidemiological studies of radiation exposures *for statistical significance*. This requires some discussion. Broadly speaking, there are two types of epidemiological studies—observational studies of (usually) expected effects where data may be known beforehand and analytical studies of (usually) unexpected or unknown effects where the data are unknown beforehand. The latter usually have defined hypotheses that can be tested with formal statistical tests, thus allowing quantitative conclusions unlikely to be due to chance and offering some proof of effect. Statistical tests are often used in the latter, but they may not be necessary in the former.

The eastern studies are mostly the former observational type. For example, they typically show cancer increases in areas of high ^{137}Cs concentrations compared with areas of low ^{137}Cs concentrations. (The question of doses is discussed below.) From the knowledge on radiation's effects, these findings are not unexpected. Radiation from exposures to ^{137}Cs can lead to increased incidences of cancers: it is not necessary to prove it again via statistical tests as if these were chance or unexpected findings. Therefore, many eastern scientists consider that there is little need to apply p-values and/or confidence intervals to their observed data. Interestingly, some western scientists[7–11] have in fact criticised the widespread practice and inappropriate use of significance testing.

The crux of the matter is that the inappropriate application and incorrect use of statistical tests allows IAEA scientists to challenge the findings of eastern European studies and to question whether the observed effects are due to chance. The problem with statistical tests is that if eastern scientists do not perform them, they are criticised on the grounds that western scientific norms are being ignored. On the other hand, if they do apply them and the data sets are too small for statistical significance (which can often be the case), western scientists often conclude—incorrectly—that there is no real effect. This

catch 22 situation makes it easy to see why, as is apparent in this volume, eastern European scientists feel perplexed: they are damned if they do test and damned if they do not.

The third way is by *requiring dose estimates* in order to establish a dose response relationship: studies not containing dose estimates are usually thereby rejected. However, as the authors point out, such demands by western nuclear agencies can be unreasonable. The authors state that because of official secrecy and obfuscation, radiation exposures to liquidators are difficult to reconstruct. This is only partly true, as western and eastern scientists[12] actually have reconstructed liquidator doses. It is more probably the case that, as such dose reconstructions take much time and are costly, resource restrictions are the real reason. A more valid reason is that estimates of internal exposures from ingestion/inhalation often have major uncertainties as shown by the report of the UK Government's CERRIE Committee[13]. Of course, it is always preferable to have dose estimates even if they are qualified by uncertainties. It may be possible, for instance, to look at different groups with low, medium and higher levels of exposure.

In the views of IAEA and WHO, the large observed increases in morbidity and mortality are explained possibly by confounding factors, possibly by other causes of death, possibly by increased medical surveillance, possibly by social breakdown and possibly by psychological depression. However, few studies are carried out to provide evidence of these assertions.

CONCLUSION

Clearly, there is a continuing and profound difference of views over Chernobyl's health effects. Some readers will disagree with the discussion presented in this volume and will consider its authors to be too polemical in their views. On the other hand, others will concur with the book's findings. The author's view is that there is much valuable information here, notwithstanding western criticisms of eastern science's protocols. This does not necessarily mean every detailed point in these summaries is accepted without question. For example, as shown above, more attention needs to be paid to the large recent decrease in average male life spans in Belarus, Russia and Ukraine in all areas not just contaminated ones. Also greater efforts should be made in reconstructing doses (and resources be made available for this), and in estimating individual and collective doses and discussing their implications for both eastern and western Europe.

Nevertheless, the publication of summaries of hundreds of research reports on the health and environmental consequences of Chernobyl originally published in Russian and Ukrainian is a welcome addition to the literature in English. The New York Academy of Sciences, which states that it '. . . has a responsibility to provide an open forum for discussion of scientific questions', is therefore to be congratulated for publishing this volume. The English translations will certainly permit more informed dialogue to take place.

In the opinion of the reviewer, this volume makes it clear that international nuclear agencies and some national authorities remain in denial about the scale of the health disasters in their countries due to Chernobyl's fallout. This is shown by their reluctance to acknowledge contamination and health outcomes data, their ascribing observed morbidity/mortality increases to non-radiation causes, and their refusal to devote resources to rehabilitation and disaster management.

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CHERNOBYL: CONSEQUENCES OF THE CATASTROPHE FOR PEOPLE AND THE ENVIRONMENT

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In the few weeks before I was asked to review this book there was media coverage of two diametrically opposed views regarding the magnitude of health effects associated with the Chernobyl reactor accident. One is expressed in the book under review and the other came from Zbigniew Jaworowski (former chair of the United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR).The opposing positions are placed either side of the 'middle ground' as expressed by organisations such as International Atomic Energy Agency (IAEA), UNSCEAR and WHO.

In the context of the Chernobyl accident Jaworowski[1] criticises publications, which use a linear-no threshold (LNT) dose response to evaluate cancer risks at very low doses and contrasts predictions of thousands of late cancer deaths with deficits (compared with Russian national statistics) of solid cancers in Russian emergency workers and the populations of most contaminated areas. He claims that the application of LNT led to the unnecessary 'sufferings and pauperisation' of millions of inhabitants of contaminated areas. In contrast to the views of Jaworowski the current book under review by Yablokov *et al*., considers that the excess cancer cases related to the Chernobyl accident have been grossly underestimated.

In the opinion of this reviewer, the wide range of estimates that can be found in the scientific literature is mainly due to different estimates of population dose, the use of different radiation risk figures and different interpretations of epidemiological data (particularly the use of different control groups). Published estimates of excess deaths also frequently differ in terms of which countries and time periods they refer to. This often makes meaningful comparisons difficult or impossible although it often remains clear that there is a large disparity between different authors. With such a range of views, an already vast and increasing literature, and claims that there has been coercion on an international scale, how can professional scientists—such as most readers of this review—arrive at an informed opinion on the radiation-related adverse health effects from the Chernobyl accident? The answer is with great difficulty! I personally find it necessary to critically read at least selected contributions from the whole spectrum of views. For that purpose this book covers the high cancer mortality tail of the distribution of predictions of health effects from Chernobyl.

This book is a collection of papers translated from an earlier publication in 2007in Russian. The book presents data which it claims have been inexplicably omitted or inadequately considered by various international bodies such as IAEA and United Nations Agencies. It concludes that previous assessments of adverse health effects arising from the Chernobyl accident have been grossly under-estimated. The foreword by Prof. Grodzinsky (Chairman of the Ukrainian National Commission on Radiation Protection) proposes an explanation for this omission in terms of the influence of a pro-nuclear lobby, which has inhibited the funding of medical studies, diverted human resources away from Chernobyl