My review, based on nearly thirty years of research on Chernobyl and dozens of visits to the contaminated areas of Belarus, Ukraine and Russia, argues that *Manual for Survival* ignores the thousands of scientific studies on Chernobyl which are available in the international scientific literature. In doing so, it presents a biased and misleading account of the health and environmental effects of the accident. I believe that this book only perpetuates the many myths about the accident effects and has very little basis in sound science.

**Keywords:** review, Chernobyl, health, radiation, radioactivity

*Manual for Survival* is an interesting, but deeply flawed history of the health and environmental impacts of Chernobyl, the worst technological disaster in human history. It would be all too easy to dismiss it for its multiple omissions, inconsistencies and errors. But it is important that we in the radiation protection community take it seriously and respond in detail to its claims—of major low-dose radiation effects we have missed—with clear evidence and explanation of why we think it is wrong in a way which non-specialists can clearly understand. With the notable exception of Mikhail Balonov’s response [1] to the Yablokov [2] Chernobyl report I think it is something we have failed to do with previous claims of major low-dose radiation effects after Chernobyl.

I was interviewed by Kate Brown for this book at a meeting in Florida on radiation effects on wildlife at Chernobyl. For about an hour and a half I was subjected to what felt to me like an aggressive cross-examination on a huge range of subjects relating to radiation, including the Hiroshima and Nagasaki bomb survivor studies, cancer, wildlife effects, contamination of food and dose reconstruction. I answered all her questions and where I had doubts later followed up with information and evidence. I emerged from the interview feeling mentally exhausted (really!) but nevertheless happy, even a little elated. Despite my reservations about her scientific knowledge, here, I felt, was a serious and unbiased historian.
determined to get to the truth about the hugely complex and controversial issue of the health and environmental consequences of Chernobyl.

I was wrong.

On getting the review copy of this book I couldn’t help but turn first to the pages dealing with my interview (I guess most people would do the same). I was shocked and disappointed to find that the information and opinions I had given on radiation effects on wildlife at Chernobyl had been dismissed. According to Brown, I was a physicist (used almost as a term of abuse in the context) who didn’t feel it necessary to go to Chernobyl to draw my pre-formed conclusions about the accident effects. Brown did not report what I had told her—I first studied Chernobyl fallout in the English Lake District in 1990 and first did fieldwork in the Chernobyl affected areas of Ukraine and Belarus in 1994. I clearly remember being quite worried about what were—to me at that time—largely unknown risks of radiation at Chernobyl. I have stopped counting the number of times I have visited the Chernobyl contaminated areas since, but I guess it is around 40. I am happy to be argued with, but it is poor and biased scholarship to dismiss my evidence (and that of my Belarusian colleagues who worked in the Exclusion Zone for many years).

This, I think, is just one symptom of a deeply flawed approach to the complex information on Chernobyl, but I’ll try to give this book as fair a review as I can. You can judge whether I have achieved that, but will certainly be more in-depth than the rather superficial and misleading reviews provided by Nature [3] and a number of other journals and newspapers.

**Dosimetry and dose reconstruction**

The treatment of radiation dose and dose estimation is unquestionably biased in this book. The author wishes to make the argument that ‘the physicists’ have got it wrong about radiation doses after Chernobyl. She begins with a description of an interview with Lynn Anspaugh, an internationally respected radiation expert who, amongst other things, co-led the 2006 IAEA ‘Environmental’ Chernobyl Forum report [4]. In my brief experience of contact with him during the preparation of the report, I found him to be hugely knowledgeable about the many aspects of radiation and dose reconstruction after Chernobyl. Kate Brown apparently didn’t come to the same conclusion. From her telephone interview, she takes one piece of information—that early-on, Anspaugh (presumably estimating total Global contamination from Chernobyl) took just two data points to estimate fallout in the whole of Romania. She then uses this piece of information to attempt to discredit the entire field of radiation protection dosimetry! I guess, as a good scientist, Anspaugh realised that in an initial estimate of impacts of Chernobyl (there have been many much better estimates since including the Russia/Belarus/Ukraine/EU Atlas [5] and many more), that the fallout in Romania wasn’t going to make too much difference and he made the best estimate he could.

What is astonishing (literally, jaw-droppingly astonishing) is that Manual for Survival fails to mention, in the section of the book dealing with dosimetry, all the measurements conducted in the years after the accident both in the former Soviet countries and abroad. I believe Brown that in Soviet times, information on these was (unforgivably) kept secret, but it is there and now you don’t have to dig around in Soviet archives to find it: reports and results (but sadly not all the original data) have been in the international scientific literature for more than 20 years. For example, in his paper for the 1996 Minsk conference [6], Mikhail Balonov reported ‘one million measurements of $^{134}$Cs and $^{137}$Cs in the body’.

338
Those seeking to criticise the consensus on Chernobyl often accuse scientists of only focusing on one isotope—radiocaesium. It’s true that there are far more measurements and studies on caesium than on other isotopes, because it is relatively long-lived and can be reasonably cheaply and easily measured by gamma spectrometry and whole body counting. But that doesn’t mean that other isotopes were ignored: the scientific literature contains many papers on many other isotopes, including $^{131}$I, $^{90}$Sr and transuranium elements which Brown could have referred to, but chose not to. Balonov’s short paper alone [6] mentions hundreds of $^{90}$Sr measurements, discusses the change in isotopes contributing to dose over time since the accident and presents dosimetry models which include the key isotopes needed for long term prediction. There are many others presenting dose reconstruction models. Brown makes much of the ‘cocktail’ of radionuclides residents were exposed to, in particular $^{90}$Sr: this has also been covered in the scientific literature. Balonov [6] states ‘...due to the low content of $^{90}$Sr in the Chernobyl release and [low] fallout outside the 30-Km Zone its contribution to the internal effective dose does not exceed 5%–10%, according to intake calculation and direct measurements of $^{90}$Sr in human bones (autopsy samples). Similar contribution from the inhalation of $^{239-241}$Pu, $^{239}$Pu and $^{241}$Am originated from $^{241}$Pu will not exceed 1% even for outdoor workers’. There is a wealth of other information on all aspects of dosimetry in the scientific literature amounting to hundreds, likely thousands of articles. Again, Brown doesn’t have to believe Balonov and all the other scientists, but to omit this evidence is shocking.

Having dismissed ‘the physicists’ method of dose estimation and reconstruction, Manual for Survival goes on to argue that ‘the physicians’ had a much better method which was ignored. She cites work by Vorobiev (I haven’t seen this Russian language work, but will try to get hold of a copy) which claims a biodosimetry method based on analysis of chromosome damage which is much more accurate than whole body counting and dose reconstruction. This method seems to give much higher accumulated doses than ‘the physicists’ methods.

Is it true that biodosimetry methods are better than physical measurements and models? As far as I know, the radiation protection community only uses biodosimetry to reconstruct doses after high exposures which couldn’t be evaluated using physical methods. Even the most recent attempts (using much more sophisticated technology than was available in 1986) to develop a unique radiation biomarker for low dose exposure have failed. I checked this with Geraldine Thomas, Professor of Molecular Pathology at Imperial College and she confirmed (pers. comm) that biodosimetry only works well for high doses. That is not to say that such attempts are not valuable, just that there is very little support for Brown’s claim that biodosimetric methods in the former Soviet Union were better than direct measurement of gamma-emitters and dose reconstruction for other nuclides.

Effects on wildlife

This section is so biased and misleading that I hardly know where to start. Brown has chosen to believe the evidence of Anders P. Møller and Tim Mousseau that there are major effects of radiation on organisms at Chernobyl at dose rates much lower than expected, and that wildlife is severely damaged in the Chernobyl Exclusion Zone (CEZ). In other parts of the book, Brown is careful to question the veracity of her sources. But surprisingly she fails to mention: Anders P Møller is a highly controversial scientist (in radioecology and in his previous field of evolutionary biology): an article in Nature reports that he was once found guilty of manipulating data by the Danish Committee on Scientific Dishonesty (Nature 427 381, 2004). This doesn’t automatically mean he and Mousseau are wrong about the extent of Chernobyl effects, but there is plenty of evidence that they are, e.g. [7–11]. Brown dismisses the evidence of my colleagues (including Belarussian scientists) and me by calling me a physicist
and implying that I have never been to Chernobyl. Interestingly, in the apparently meticulously constructed list of footnotes, she cites our paper (showing abundant mammal populations in the CEZ) wrongly as ‘Smith et al.’ rather than ‘Deryabina et al.’ as it should be since Tatiana Deryabina was first author. Is it an error (we all make them)? Unfortunately, this error hides the fact that Belarussian scientists were a key part of the study so that Manual for Survival can argue (wrongly) that it was done by someone with no knowledge of the CEZ.

The omissions in this section are shocking. Brown has not talked to and does not mention the one person in the world who is most closely associated with wildlife at Chernobyl: Sergey Gaschak. Sergey (much to his frustration at times) is the person who journalists always seem to go to to find out about wildlife in the CEZ. Brown may not agree with Gaschak’s opinion (formed from 30 years in the Zone and an intimate knowledge of the Zone’s habitats and wildlife) that wildlife is not significantly affected by radiation at Chernobyl, but she should at least report it. Gaschak initially worked with Møller and Mousseau but refused to continue: he didn’t trust their reporting of data, particularly on the influence of habitat on bird distribution [12]. Brown does not discuss the work of Ron Chesser and Robert Baker at Texas Tech University who spent many years studying small mammals in the Red Forest hot spot. They found that small mammal abundance was similar in the Red Forest to control areas [13] and that genetic effects were subtle. Chesser and Baker’s thoughts on their long experience of radioecological research at Chernobyl are essential reading for an understanding of this issue. Again, you don’t need to dig in Soviet archives: their article, ignored in Manual for Survival, is in American Scientist [14].

Health effects and chronic radiation sickness

My faith in Brown as an accurate reporter of radiation health effects was a bit shaken when I was interviewed by her. Despite having already written Plutopia (Oxford University Press, 2013), her fascinating, but scientifically flawed, account of the US and Soviet nuclear weapons programmes, she very clearly did not know that non-radiation related cancer was very common across the world. There are a myriad of health statistics on this, but you don’t need to look that far: Cancer Research UK, for example, state on their website (and advertising) the projection that half of UK citizens will get cancer at some point in our lives. I was further shocked to read in this Chernobyl book (p 25) Brown’s bald statement that radiation is the only known cause of myeloid leukemia, in the context clearly implying (wrongly) that there are no other causes. Brown did not consider or cite any of the public health statistics on myeloid leukemia incidence in countries worldwide. Nor does she cite the Hiroshima and Nagasaki Life Span Study (LSS) report [15] which clearly presents evidence that radiation is a cause of myeloid leukemia (very significant at high doses), but is very far from being the only cause, particularly at low dose rates. Nor does she cite her own statement on p 168 that ‘radiation damage is hard to isolate and detect because it causes no new, stand-alone illnesses’.

The most controversial claim in this book is that very low dose radiation causes Chronic Radiation Sickness. Chronic Radiation Sickness is real, having first been seen (but recognised late) at very high dose rates in radium dial painters a century ago. It was seen in highly-exposed workers at the Mayak Plutonium Production Plant where it was first diagnosed and treated by Angelina Gus’kova. In the first part of Manual for Survival, Gus’kova is rightly described as a scientific hero (‘No-one in the world had treated more patients with radiation illness than Gus’kova’ p 13; ‘Working on hundreds of patients … over three decades, Gus’kova developed a compendium of knowledge on radiation medicine that had no
equivalent in the world’ (p 15). As detailed in *Manual for Survival*, Gus’kova’s work treating the early victims of Chernobyl (the 134 people suffering from Acute Radiation Syndrome) saved and extended many lives. Brown contrasts Gus’kova’s deep understanding of radiation sickness with the relative inexperience of the American doctor, Robert Gale, who flew in to help treat the victims. Brown argues, powerfully, that Gale thought he knew better than the Soviet scientist and ignored her expertise.

Sadly, the American doctor wasn’t the only person to ignore Angelina Gus’kova’s expertise: Brown herself does so. Gus’kova not only treated sufferers of Acute Radiation Sickness, but also checked evacuees and took part in the study of the ‘liquidators’, the hundreds of thousands of people who worked on the Chernobyl clean-up operation in 1986 and 87 and who received some of the highest radiation doses. In a 2012 article, Gus’kova [16] stated that ‘In contrast to the first group [the 134 ARS victims], this second group of individuals working within the 30-km zone, just as the population exposed to radiation [my emphasis], did not exhibit any manifestations of radiation sickness.’

So, the world-leading expert in chronic radiation sickness has stated that she did not believe that either the huge liquidator group, or the population exposed to chronic, relatively low dose rate radiation suffered from radiation sickness. Kate Brown would doubtless argue that Gus’kova’s high status in Soviet and Russian atomic science made her ignore evidence to the contrary. Whether you believe Gus’kova or not (I do), for Brown to exclude this key evidence from a history book about the health effects of Chernobyl is an omission of monumental proportions.

*Manual for Survival* argues that Western scientists knew less about the health effects of radiation than their Soviet (and post-Soviet) counterparts. Evidence of apparent damage to health of adults, children and newborns in the contaminated regions is cited from archival material in Ukraine and Belarus. Brown claims that the Hiroshima and Nagasaki Life Span Study (on which the system of radiation protection is largely, but far from wholly, based) missed many early effects of radiation since it only started in 1950, five years after the bombs were dropped. This is partly, but not wholly, true: effects of fetal exposure could be, and were, studied [17]. Effects on children due to pre-conception exposure of their parents was studied and no effects were found [18] allowing an upper limit on risk of inter-generational mutation damage to be estimated.

Discounting the Life Span Study evidence allows Brown to argue that radiation is much worse than UN organisations and the International Commission on Radiological Protection (ICRP) believe (though note that these organisations consulted and had as members key former Soviet scientists, including the radiation sickness expert Angelina Gus’kova). Astonishingly, however, *Manual for Survival* ignores almost all the other international scientific evidence on this issue. Hundreds of footnotes detail Soviet and former-Soviet sources, but there are barely any citations from the many epidemiological studies (not just the LSS) and thousands of radiobiological studies in the international scientific literature (see, for just one example, the Oxford Restatement on this issue [19]). The few international sources which are cited are those (some of them highly controversial) which agree with Brown’s various contradictory and confusing hypotheses.

What of the public health statistics apparently showing huge increases in birth defects, cancers and a wide range of other illnesses in the populations of the contaminated territories? Though Brown has apparently uncovered new archival evidence (which should be evaluated, if they have not already been), I am highly skeptical. I suspect (but don’t know) that much of this evidence is similar to that presented in the controversial Yablokov report [2] claiming nearly a million deaths from Chernobyl. I’m not an epidemiologist, but I have tried to take a look at these claims.
Firstly, I looked again at the 2006 WHO Chernobyl Forum Report [20]. The 45 international experts (including experts from Belarus, Ukraine and Russia) evaluated a wealth of data on health effects of Chernobyl. The report (strangely, hardly mentioned in Manual for Survival) covers a wide spectrum of health outcomes including cancer and non-cancer effects in adults and children as well as adverse pregnancy outcomes. It comes to a very different conclusion to Manual for Survival. Have the international experts ignored or missed key evidence? I think it very unlikely, but what to me is missing from the WHO report is a clear explanation, in lay-persons terms, of why this evidence is not included.

I’ve taken a look at some (but of course not all) of this evidence and it seems obvious to me why much of it wasn’t included in the WHO analysis. Health effects studies after Chernobyl suffered from two major problems: changes and errors in reporting before and after the accident, and a difficulty in disentangling radiation health effects from the ongoing public health crisis during and after the collapse of the Soviet Union. Both of these effects are real: they are mentioned in Manual for Survival but are discounted when claims of huge radiation health effects are being made.

Problems in health reporting. I’m currently working in the Narodichi district of Ukraine on a small project trying to make the lives of people in affected areas a little bit better by bringing abandoned agricultural land back into use, where it can be done safely. As part of the project, we spoke to Anatoly Prysyazhnyuk, a cancer-doctor and epidemiologist. Anatoly was born in Narodichi to a family of local doctors and is an Honoured Citizen of Narodichi, but was working in Kiev at the time of the accident. He told us that, in 1987, he was contacted by the head of the local hospital. The hospital chief was very worried that cancer registrations had increased significantly since the accident. Anatoly went back to his home town to investigate. He found that, indeed, cancer registrations had gone up, but that this was due to reporting changes, not to radiation. Changes in reporting of health outcomes are real and are a key consideration in interpreting health statistics as the 45 WHO experts no doubt knew.

Misuse of public health statistics. In his review of the flawed Yablokov [2] report, Mikhail Balonov [1] cites data on mortality rates across Russia since the fall of the Soviet Union [21]. As Balonov notes, mortality rates increased since 1991 in all parts of Russia, even in Siberia, thousands of miles from Chernobyl. As shown in figure 1, demographers have attributed this to economic crisis, alcohol consumption and smoking, not radiation. Trends in mortality, and other health outcomes, are compromised by this widespread health crisis. Comparing public health statistics between contaminated and uncontaminated regions is also fraught with difficulty owing to known demographic changes in the contaminated regions (younger people tended to leave, older people tended to stay).

Oddly Kate Brown accepts problems in distinguishing radiation effects in health data. Her treatment of Fred Mettler’s study of 1656 inhabitants, including children, of the affected and non-affected areas [22] is revealing of the huge contradictions at the heart of Brown’s thesis. Manual for Survival reports the finding of this study: that no significant differences could be found between 853 inhabitants of contaminated areas and 803 inhabitants of control areas. But Brown goes on to attempt to discredit this study. Firstly, she argues that doses were not different between control and contaminated regions due to trade in foodstuffs. This ignores the fact that this (as well as making little sense) was checked in the study: ‘Samples of bread, milk, vegetables and meat were also examined from these control settlements. Analysis revealed low levels of contamination, as expected’ (IAEA [22] pp 283–84).

Secondly, Brown argues that that a 1600 person study is not sufficient to find evidence of the low-probability health effects of low dose radiation. She is right, but what is astonishing that she does not apply this logic to many of the other claims in her book. In most of the book she seems to be claiming major health effects which would have been picked up by the IAEA
screening. Indeed, the report [22] includes a power analysis of the study showing what sort of health effect the study could detect. Later on in the book, Brown supports her claims of non-cancer health effects of radiation by referring to large scale studies (hundreds of thousands of subjects) which may (or may not) indicate a tiny increase in cardiovascular risk at low dose rates (of the order of the majority of doses received by the Chernobyl affected populations). But she ignores the key point: even if real, these tiny non-cancer health effects are of no significant relevance to the health of people living in contaminated areas. What they need to worry about (and often are worried about, of course), as has been pointed out many times before [23, 24], is the high rates of unemployment, poor condition of their health services, diet, nutrition, smoking, alcohol consumption etc.

This is not to say that there have been no health effects of Chernobyl. As noted by Brown, the cancer effect which can most clearly and unambiguously be attributed to radiation is thyroid cancer in children and adults exposed as children to fast-decaying I-131 in the weeks after the accident. The increase in the affected regions was large and could be seen even in national health statistics: annual incidence in Belarus, for example, increased from fewer than one case in 100 000 before 1986 to 7–8 cases per 100 000 in the 1990s [25] and remains elevated. There is evidence of a potential increase in breast cancer [26], though note that this study concluded that ‘the age-adjusted breast cancer incidence rates in the most contaminated regions of Belarus and Ukraine are still lower than in North America and Western Europe’. Other cancer incidence from dose reconstruction across Europe has been estimated by Cardis et al [27, 28], if you apply the Linear No-Threshold (LNT) hypothesis that even tiny radiation doses carry a potential risk.

Figure 1. Graphic illustrating the changes in life expectancy in Russia (not linked to radiation) from 1981–2002 [29], loss of life expectancy in the high dose group of atomic bomb survivors; smoking prevalence in former Soviet countries.
Berries with radiocaesium in Polessie

A claim in *Manual for Survival* is that, even after the initial period of iodine contamination, contaminated produce, particularly milk, was still consumed by people in the years after the accident, even though it was over the (quite cautious) limits for radiocaesium in food products in place in the former Soviet countries. Again, this isn’t a historical fact hidden in Soviet archives: it is there in the scientific literature and in official statistics of the affected countries. In my co-authored book on Chernobyl [30], we reproduced a table from Firsakova [31] showing changes in the number of kilotonnes of milk and meat from collective farms which were above intervention limits.

One of the ‘headline’ claims in *Manual for Survival* is that contaminated berries have up to 3000 Bq kg\(^{-1}\) of \(^{137}\)Cs (well above the Ukrainian limit) and that these may be being mixed with uncontaminated berries and exported to Western Europe. Of course, that is not a good thing, but is it a really bad thing? *Manual for Survival* implies that this is really dangerous, but provides no context to help the reader evaluate what the risk is. It may help to place this in context that after Chernobyl, the Norwegian government made the difficult decision to increase the limit on \(^{137}\)Cs concentrations in reindeer meat to up to 6000 Bq kg\(^{-1}\) (in 1994 it was reduced to 3000 Bq kg\(^{-1}\)) [32]. Why? Because they sensibly balanced the tiny risk to the reindeer herders, and Norwegian consumers against the damage of a ban to the lifestyles and culture of the herding community. I don’t know enough about the berry-pickers of Rivne, Ukraine to make such a decision, but Brown is wrong to imply that this is very dangerous. I’m in no way advocating allowing regulatory limits to be broken, just that breaking these very cautious limits doesn’t mean something is dangerous. As a European consumer, if I somehow managed (a vanishingly unlikely event) to eat a whole kg of the most contaminated berries, I would get an additional dose equivalent to about two chest x-rays, a return flight from Los Angeles to New York or 250 times lower than an abdominal CT scan.

The residents of Polessie are eating contaminated produce all the time: this is why we calculate the overall dose. Only a small proportion of people now living in the contaminated regions get a dose more than 2 mSv per year and the vast majority get a dose less than 1 mSv per year. These dose rates are well within the variation of natural background radiation worldwide.

Nuclear weapons testing

*Manual for Survival* argues that Chernobyl was just an acceleration of a process, damaging to the whole planet, started during the atmospheric bomb tests of the 1950s and ’60s. I agree with Brown that, if you believe in the LNT hypothesis that every small radiation dose carries a risk, then the global health consequences of atmospheric nuclear weapons testing are huge. Like many claims in *Manual for Survival*, this claim is treated as news, but it is only alarming news if you ignore the mass of scientific evidence. The UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) have published many reports on this. The estimated collective dose from atmospheric weapons testing is huge and dwarfs that of Chernobyl. But individual doses are, of course, low: UNSCEAR [33] reports peak annual total effective dose in 1963 in the region of 0.1 mSv. This is about the equivalent dose to a return flight from London–Los Angeles (from cosmic radiation) for everyone in the Northern Hemisphere and about one thirtieth of annual natural background radiation dose rates. Any extra dose above background could be a potential risk. But Brown’s vague assertion that this could be a significant cause of long term increases in cancer incidence worldwide, without any supporting evidence, is unconvincing, to say the least.
Omissions and errors

One of the major failings of this book is that the vast body of knowledge in the international scientific literature is almost completely ignored. Other omissions I noted are: no discussion of natural radioactivity, no mention of thyroid treatment by I-131, medical diagnostic doses or all the epidemiological evidence from medical diagnostic and therapeutic procedures. There are more omissions and many more errors than I have had the space to point out here.

Breaking the laws of physics

These are maybe minor points, but I think it indicates something about the poor quality of this book when I have to point out that Manual for Survival gives credence to three claims that break current Laws of Physics:

1. It apparently gives credence to the view (p 215) that nuclear weapons testing on Earth, through the vacuum of space, somehow influenced the Sun’s solar flare activity. It’s true that nuclear weapons have terrifying destructive power—the biggest are equivalent to 50 megatonnes of TNT. I could write an essay on why these couldn’t influence solar flare activity, but perhaps a comparison of relative energy is best. I studied astrophysics more than 30 years ago and have forgotten what I learnt about solar flares, so went to NASA’s website (https://visibleearth.nasa.gov/view.php?id=55580), I found that ‘solar flares…are capable of releasing as much energy as a billion megatonnes of TNT’, twenty million times bigger than the biggest nuclear bomb. Solar activity, of course, affects Earth, not least in the charged particles contributing to the cosmic and natural background radiation we all receive every day. The astonishing omission of any discussion of natural radiation doses is just another fatal flaw in Manual for Survival.

2. It reports (p 302) that ‘the period of half of $^{137}$Cs to disappear from Chernobyl forests will be between 180 and 320 years’, citing ‘Wired’ magazine. The physical decay half life of $^{137}$Cs is about 30.2 years. In the years after Chernobyl it has been pointed out many times, by me and many others, that in soils rich in organic matter, the effective ecological half life of $^{137}$Cs is approaching it’s physical decay half life (e.g. [34]). But it can’t go higher than 30.2 years, unless, of course, the Laws of Physics are wrong.

3. Kate Brown’s dosimeter was ‘jumping in alarm’ in the most contaminated Red Forest area (p 125), apparently due to a previous forest fire. I’m struggling to understand what Brown means here, but she seems to be claiming that her dosimeter was reading $1000 \mu$Sv h$^{-1}$ when normally the Red Forest reads (a very high) $50–100 \mu$Sv h$^{-1}$. Here Brown claims that a fire the previous year has caused the 10 times increase in dose rate because the fire released radioactivity. Again, there is so much wrong with this hypothesis that I hardly know where to start. Yes forest fires can release small amounts of radioactivity to the air, but why should this have a significant ($10\times$) influence on external gamma dose rates? For an understanding of effects of forest fires on radionuclide resuspension, Brown could have studied and cited previous work on this e.g. [35].

The Laws of Physics are not set in stone, and physicists make mistakes too, but I don’t think we’re going to start re-writing the textbooks yet. I’m not expecting Brown to understand all the physics of radiation protection, but I do expect her to consider the huge amount of available scientific knowledge and opinions.
What can we learn from this book?

In this review I’ve necessarily focussed primarily on the (many) flaws and omissions in the book. *Manual for Survival* is a polemic, not a history book and much less a science book. Brown is rightly angry at the Soviet (and some Western) cover-ups, the haphazard and often inefficient relocations. After Chernobyl, people got bigger doses than they needed, particularly the unforgivably large thyroid doses due to failure to prevent ingestion of $^{131}$I in the first weeks after the accident. She is also angry that the people living in the Chernobyl contaminated areas have seemingly been forgotten by the international community. International scientific and humanitarian efforts (with many notable exceptions) have been piecemeal, often with little and inconsistent funding, and have very often failed (partly due to the complexities of working in the post-Soviet countries). I would contrast the inconsistent funding for economic redevelopment in the Chernobyl contaminated areas with the about $1.5 billion committed to the New Safe Confinement and reactor decommissioning project.

I remember vividly, in the mid-1990s, studying fish at Lake Kozhanovskoe in Russia. The fish had accumulated $^{137}$Cs activity concentrations far above intervention limits, but people were still eating the fish. Naively, I asked a fisherman why he was eating these fish: he looked at me blankly—as if I had come from another world—and responded drily: ‘what do you expect me to eat?’. At the time, there was little food in rural shops. At that point, I realised that the radioactivity in the fish was the least of the fisherman’s problems.

I’m angry that too often, both in the affected countries and abroad, myths about radiation have been spread: I think these do real damage to people’s lives and have undoubtedly hampered recovery from the disaster. *Manual for Survival* perpetuates many of those myths, but I think we should learn from it. I’m also angry at myself, and my scientific field for not having worked harder to counter those myths. Kate Brown has a journalist’s skill in capturing the individual tragedies of many people’s lives in the Chernobyl contaminated lands and she puts this to good use in describing her many visits to these areas. The problem is real, but I think the diagnosis offered in *Manual for Survival* is very wrong and damaging. People in the Chernobyl affected areas need more jobs, more economic development, better healthcare and better nutrition. Current radiation should be the least of their concerns, though I understand why many (not all) still worry.

Acknowledgments

I currently have funding from the UK Natural Environment Research Council project iCLEAR—Innovating the Chernobyl Landscape: Environmental Assessment for Rehabilitation and Management (NE/R009619/1).

Conflict of interest

I have previously had a small amount of funding from the nuclear industry and a larger project from the NERC part funded by Radioactive Waste Management and the UK Environment Agency. This will likely be perceived by some as a conflict of interest. I am proud to be making a small contribution to helping the clean-up of the UK’s nuclear waste legacy and to a debate on the future of nuclear power which is based on scientific evidence.
References

[1] Balonov M I 2012 On protecting the inexperienced reader from Chernobyl myths J. Radiol. Prot. 32 181
[2] Yablokov A V, Nesterenko V B, Nesterenko A V and Sherman-Nevinger J D 2010 Chernobyl: Consequences of the Catastrophe for People and the Environment vol 39 (New York: Wiley)
[3] Schmid S 2019 Chernobyl: data wars and disaster politics Nature 566 450–1
[4] Alexakhin R 2006 Environmental consequences of the Chernobyl accident and their remediation: twenty years of experience. Report of the Chernobyl forum expert group ‘Environment’ (Vienna, Austria: International Atomic Energy Agency)
[5] De Cort M et al 1998 Atlas of caesium deposition on Europe after the Chernobyl accident. Catalogue number ‘CG-NA-16-733-29-C’. EUR 16733 (Luxembourg: Office for Official Publications of the European Communities 1998) pp 1–63
[6] Balonov M, Jacob P, Likhtarev I and Minenko V 1996 Pathways, levels and trends of population exposure after the Chernobyl accident The Radiological Consequences of the Chernobyl Accident 235–49
[7] Bonzom J-M et al 2016 Effects of radionuclide contamination on leaf litter decomposition in the Chernobyl Exclusion Zone Science of the Total Environment 562 596–603
[8] Lecomte-Pradines C et al 2014 Soil nematode assemblages as bioindicators of radiation impact in the Chernobyl Exclusion Zone Science of the Total Environment 490 161–70
[9] Deryabina T et al 2015 Long-term census data reveal abundant wildlife populations at Chernobyl Current Biology 25 R824–6
[10] Webster S C et al 2016 Where the wild things are: influence of radiation on the distribution of four mammalian species within the Chernobyl exclusion zone Frontiers in Ecology and the Environment 14 185–90
[11] Zach R, Hawkins J L and Sheppard S C 1993 Effects of ionizing radiation on breeding swallows at current radiation protection standards Environmental toxicology and chemistry 12 779–86
[12] Gaschak S COMET Deliverable (DN 5.6). Thirty years after the Chernobyl accident: what do we know about the effects of radiation on the environment COMET Workshop Report pp 20–22
[13] Baker R J et al 1996 Small mammals from the most radioactive sites near the Chernobyl Nuclear power plant Journal of Mammalogy 77 155–70
[14] Chesser R K and Baker R J 2006 Growing up with Chernobyl: working in a radiactive zone, two scientists learn tough lessons about politics, bias and the challenges of doing good science Am. Sci. 94 542–9
[15] Hsu W-L et al 2013 The incidence of leukemia, lymphoma and multiple myeloma among atomic bomb survivors: 1950–2001 Radiat. Res. 179 361–82
[16] Gus’kova A K 2012 Medical consequences of the Chernobyl accident: aftermath and unsolved problems Atomic Energy 113 135–42
[17] Yamazaki J N and Schull W J 1990 Perinatal loss and neurological abnormalities among children of the atomic bomb: Nagasaki and Hiroshima revisited, 1949 to 1989 J. Am. Med. Assoc. 264 605–9
[18] Douple E B et al 2013 Long-term radiation-related health effects in a unique human population: lessons learned from the atomic bomb survivors of Hiroshima and Nagasaki Disaster Medicine and Public Health Preparedness 5 S122–33
[19] McLean A R et al 2017 A restatement of the natural science evidence base concerning the health effects of low-level ionizing radiation Proceedings of the Royal Society B: Biological Sciences 284 20171070
[20] Bennett B, Repacholi M and Carr Z Health effects of the Chernobyl accident and special health care programmes. Report of the UN Chernobyl Forum Expert Group ‘Health’ (Geneva, Switzerland: World Health Organization)
[21] Men T, Brennan P, Boffetta P and Zaridze D 2003 Russian mortality trends for 1991–2001: analysis by cause and region Brit. Med. J. 327 964
[22] IAEA 1991 *The International Chernobyl Project Technical Report*. 640 (Vienna: International Atomic Energy Agency)
[23] WHO 2004 *Health Effects of the Chernobyl Accident and Special Health Care Programmes Report on the UN Chernobyl Forum Expert Group ‘Health’* (Geneva: World Health Organization)
[24] UNDP U and UN-OCHA W 2002 The human consequences of the Chernobyl nuclear accident—a strategy for recovery *Report commissioned by UNDP and UNICEF with the support of UN-OCHA and WHO*
[25] Kenigsberg J E and Buglova E E Springer 2005 *Chernobyl: Catastrophe and Consequences* vol 310 eds ed J T Smith and N A Beresford pp 217–37
[26] Pukkala E et al 2006 Breast cancer in Belarus and Ukraine after the Chernobyl accident *International Journal of cancer* **119** 651–8
[27] Cardis E et al 2006 Cancer consequences of the Chernobyl accident: 20 years on *J. Radiol. Prot.* **26** 127–40
[28] Cardis E et al 2006 Estimates of the cancer burden in Europe from radioactive fallout from the Chernobyl accident *Int. J. Cancer* **119** 1224–35
[29] Gavrilova N S, Semyonova V G, Evdokushkina G N, Gavrilov L and Ivanova A E 2003 *Annual Meeting of the Population Association of America* pp 191–215
[30] Smith J T and Beresford N A 2005 *Chernobyl: Catastrophe and Consequences* (Berlin: Springer) pp 191–215
[31] Firsakova S 1993 Effectiveness of countermeasures applied in Belarus to produce milk and meat with acceptable levels of radiocaesium after the Chernobyl accident *Sci. Total Environ.* **137** 199–203
[32] Liland A, Lochard J and Skuterud L 2009 How long is long-term? Reflections based on over 20 years of post-Chernobyl management in Norway *J. Environ. Radioact.* **100** 581–4
[33] UNSCEAR 2000 Exposures to the public from man-made sources of radiation *Sources and Effects of Ionizing Radiation* vol 1 (Herndon, VA: United Nations Publications)
[34] Smith J T et al 2000 Pollution: Chernobyl’s legacy in food and water *Nature* **405** 141
[35] Kashparov V et al 2000 Forest fires in the territory contaminated as a result of the Chernobyl accident: radioactive aerosol resuspension and exposure of fire-fighters *J. Environ. Radioact.* **51** 281–98