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BOOK REVIEWS

Radiation and Reason: The Impact of Science on a Culture of Fear Smoking Kills: The Revolutionary Life of Richard Doll IAEA Safety Standards Series No SSG-2: Deterministic Safety Analysis for Nuclear Power Plants Handbook of Anatomical Models for Radiation Dosimetry

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Book reviews

Radiation and Reason: The Impact of Science on a Culture of Fear
Wade Allison
York: York Publishing Services (2009)
ISBN: 0-9562756-1-3 (216 pp)

Professor Allison is concerned with the threats to society posed by socioeconomic instability and climate change. Furthermore, he considers that these threats should be addressed through a major switch in our sources of energy, with nuclear power making a large contribution to the new mix. These concerns are widely shared and the solution proposed is one that is broadly accepted, though there are radical groups that advocate solutions that do not involve expansion of nuclear generating capacity (see, e.g., Makhijani 2007). Additionally, Professor Allison believes that the risks of exposure to ionising radiation have been grossly overestimated by international agencies and national regulators, and that this overestimation penalises the development of nuclear power generating capacity and leads to an unbalanced approach to energy policy. This is a much less widely held view, though it is implicit in the position taken by proponents of threshold arguments and radiation hormesis. Furthermore, it is a view that deserves detailed exploration from a number of different aspects, e.g. whether a threshold exists, the degree to which that threshold might depend on individual susceptibility or the exposure regime, and whether some risks are so small that they should be discounted by the individual and society. However, Professor Allison does not make such arguments. Rather, he assumes that he is right, and targets his book at a wide public, with the intent of winning them over to his point of view by the exercise of rhetoric and simplistic, misleading analogies.

Although targeted at the general reader, *Radiation and Reason* rather misses the mark. This is not because of the inclusion of equations or jargon, but because Professor Allison cannot decide whether he is writing directly for a wide public or addressing fellow professionals who should be bringing the argument to a wider audience. For example, in the introduction to chapter 9 we read that ‘Confidence with radiation would be developed by making simple instruments cheaply available...’. This is directed more at the policy maker than the interested member of the public.

Two hallmarks of the book are a belief in the fundamental truth of utilitarian ethics and that all that is necessary for people to make rational choices is for them to be adequately informed. The argument that ‘(m)any people would, willingly, give up 2 weeks of life for the benefit of their children or grandchildren if that would really benefit the large-scale prospect for the planet’, which itself is based upon an unverified hypothesis and confounds a trade-off in which they have a personal (and evolutionary) interest with one in which they have only an impersonal, altruistic interest, is taken to lead directly to ‘so thinking straight, a lifetime risk of death of one in a thousand is sensible—if undertaken for a good reason’. However, little consideration is given to the many factors that influence how we perceive different risks of death or that determine the good reasons or causes for which we will make sacrifices. These issues are well addressed in a book I have reviewed previously (Breakwell 2007). In particular, the issue of equitability between those who incur risks and those who benefit from the activities that give rise to the risks is not addressed. The author does not recognise that there may be legitimate different views on appropriate trade-offs between risks and benefits. Rather, he considers that there is some absolute ‘actual safety’ (page 13) and that ‘once actual safety has been established, apparent safety becomes a matter for education, communication and information.’ The concept of negotiation between stakeholder groups with different interests or of consensus building to agree a way forward does not get much attention.

Another concept that is fundamental to the author’s argument is that of non-linear responses. His arguments are primarily rhetorical rather than technical. For example, at the beginning of chapter 4 he introduces the concept by stating that ‘very loud music can damage hearing, and too much sun causes sunburn. However, a little sunshine is positively good for the skin by promoting the production of important vitamins. Similarly music that is not too loud may be positive and uplifting.’ If the author is not claiming some commonality of mechanisms between the effects of these agents and ionising radiations, and I do not think that he is making such a claim, then these analogies are empty of content. As to the linear no-threshold model, the author gives a historically inaccurate account when he claims that this model was developed and applied in 'earlier decades' when 'knowledge of cell biology was too primitive to provide confident understanding'. Rather, this model emerged and was refined as cell biology matured and studies of cell killing and cell mutation were pursued to low doses. Early radiation protection was oriented much more to protection against threshold effects, e.g. erythema.

Another false analogy used by the author is the relationship between mechanical stresses placed on a bridge and its response in terms of recovery to its original state or degradation and failure. The reader is invited to visualise cellular damage in these terms, but this model is far removed from the ways in which DNA becomes damaged and is subject to biochemical repair processes. It would be far better to address directly the processes by which DNA becomes damaged by radiation tracks and the biochemical mechanisms involved. The author eventually gets round to giving a more relevant account some forty pages later (page 82 onwards). There he distinguishes readily repaired single strand breaks from double strand breaks that are less frequent and that 'can still be repaired but may be mis-repaired'. The concern that mis-repaired cells may progress to malignancy is glossed over in the sentence 'A further level of protection is needed to cope with these.' Although the argument is not very fully developed, Professor Allison appears to believe that such protection is fully effective at the whole cell level. He comments that 'cells may die of their own accord, they may be encouraged to die by inter-cellular signalling or they may be attacked.' He then argues that 'these mechanisms provide discrimination in favour of cells recognised as native over those that are changed or are foreign.' This may be so in many cases, but it is not universally true or the changed cells that constitute cancers at different stages of development would be completely eliminated, to the benefit of human health. Here, Professor Allison seems to have confused the unlikely with the impossible. The concept of mis-repair of DNA, that gives a cell a proliferative advantage and that results in a clone in which additional changes can occur that further enhance that proliferative advantage, seems to be outside the framework of his conceptual model.

A brief summary is then provided of the available epidemiological data. This focuses on experience from Hiroshima and Nagasaki. It compares actual and expected deaths in different dose groups, but without presenting any analysis of the trend in the results with dose. Notwithstanding the excess risk of solid cancers in the 5–100 mSv range (table 5, page 91), it argues that 'the evidence for a radiation-induced effect is confined to those with a dose above 100 millisievert.' This argument is justified in the text by aggregating, without explanation, the statistics for the <5 mSv and 5–100 mSv groups. This casual use of statistics is then aggravated by confusing absence of evidence with evidence of absence: 'these data show that there is an effective threshold at 100 mSv'. They show nothing of the kind, rather that the data run out of epidemiological power somewhere around (but possibly below) 100 mSv.

There then follows a digression on medical diagnostic scans that is peripheral to the main argument, but seems directed at suggesting that as there is no risk at doses of less than 100 mSv, it would be a good thing to increase doses to improve image quality. In view of the weakness of the arguments for a threshold presented previously, this seems to me to be a highly irresponsible suggestion, particularly in the context of increasing per caput medical exposures and the relatively high doses per exposure arising from CT scanning.

In respect of Chernobyl, Professor Allison suggests that the increase in incidence of thyroid cancer was due to the poor iodine status of the exposed population. In this, he goes beyond the well known observation that I-131 uptake to the thyroid decreases as stable iodine intake increases. Rather, he maintains that there is an additional protective effect such that 'if thyroid health is maintained by sufficient intake of iodine under normal circumstances, the incidence of cancer might be substantially reduced, compared with Chernobyl.' This is an interesting speculation, but it does not justify the exclusion of excess cancers at Chernobyl from the compilation in table 8. However, I agree with Professor Allison's more general conclusion that there was an over-reaction to Chernobyl relative to other disasters with a human component. For example, would that we had an international organisation with teeth to ensure compliance with appropriate building regulations in earthquake-prone countries.

From the chapter on multiple doses of radiation, I single out one sentence to indicate the insufficiency of the argument: 'If LNT was applicable, we should expect RBE to be the same for photons and all radiation—that is unity.' The author seems to think that the only difference between high- and low-LET radiations is a different load on local repair mechanisms. The concept that the underlying lesions might differ seems alien to his understanding. Much of the remainder of the chapter relates to approaches to radiotherapy. This might seem peripheral to the main line of argument, but the fractionation regimes adopted are used to argue that tissue repair times are ~ 1 day. The author 'cautiously' then adopts a repair time of one month and argues that if a single dose of 100 mSv causes no detrimental effect, then 100 mSv per month delivered indefinitely will also cause no detrimental effect. Equating tissue damage in radiotherapy with cellular damage that may give rise to cancer, and assuming the perfect effectiveness of repair under chronic irradiation, are casual unsubstantiated assumptions that cannot be used to justify a relaxation in protection standards.

Later chapters consider a miscellany of topics including fission and fusion reactors, nuclear weapons and waste disposal. These chapters are highly judgemental and seem to represent the feelings of the author rather than reasoned argument. For example, I contrast 'The long-term solution to the need for large scale energy supply is nuclear fusion power...it may be expected in a generation or two, well within the life of the latest fission power stations' (page 187) with the description of carbon capture 'At best, it is a small component of the overall solution to the energy problem; at worst it is an expensive idea, fraught with risk' (page 153). Although significant production of power from fusion may occur, it is by no means guaranteed and has been on the horizon of a generation or two ever since the 1950s, whereas the author indulges in talking up the risks of carbon capture in just the same way as he has accused others of talking up the risks of exposure to ionising radiations.

In summary, this is a deeply flawed book. The author has convinced himself that the radiobiology and radiation protection community is badly misguided, and sees himself as providing a spotlight of illumination. I think that this is unfair and inappropriate. While there are entrenched positions, my experience is that the community has continually been open to debate and that discussion of the issues raised by the author has been much more careful and nuanced than he suggests. Furthermore, by claiming to write a popular book, the author has allowed himself to voice contentious opinions in a context that precludes him from providing detailed, technical arguments to support them.

References

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Makhijani A 2007 *Carbon-free and Nuclear-free: A Roadmap for US Energy Policy* (Takoma Park, MD/Muskegon, MI: IEER Press/RDR Books)

Mike Thorne

Smoking Kills: The Revolutionary Life of Richard Doll

Conrad Keating

Oxford: Signal Books (2009)
£17.99 (hbk), ISBN 978-1-904955-63-4 (352pp)

Richard Doll was for many a secular saint. This excellent biography by medical historian Conrad Keating will not disappoint them. The author tells in a compelling way how Doll's epidemiological work contributed so much to human well-being. He also describes his subject's life in London and Oxford. As the title of the book implies, Doll's reputation rests mainly on the study of smoking and mortality; the subtitle hints at his social and scientific radicalism. But his work went beyond smoking, and in time he became—in his own words—'one of the establishment'.

The bare biographical facts are as follows. Richard Doll was born in 1912 into a well-to-do London family, studied medicine at St Thomas's Hospital London, and served as a medical officer in the Second World War. In 1947 he joined Bradford Hill (who would later devise the eponymous criteria of causality) in the Department of Statistics at the London School of Hygiene and Tropical Medicine, while practising clinical medicine part-time. From his student days in the 1930s until the suppression of the Hungarian uprising by the Soviet army in the fifties, Doll was a member of the Communist Party. In 1962 he became director of the Statistical Research Unit of the Medical Research Council (MRC) in London, in 1969 Regius Professor of Medicine at the University of Oxford, and in 1979 he founded Green College Oxford named after an American benefactor. At Oxford he also helped to found the Cancer Epidemiology and Clinical Trials Units of the Imperial Cancer Research Fund (ICRF) in which he worked right up to his death in 2005. Doll gained many distinctions: in 1966 he was elected a Fellow of the Royal Society, in 1971 he received a knighthood, and in 1996 he became a Companion of Honour for services of national importance.

Two papers in the *British Medical Journal* encapsulate Doll's work on smoking. The first in 1950 with Hill was a case-control study of some 700 patients in London hospitals with lung cancer and a similar number of general patients as controls. The authors reached the cautious—and unpopular—conclusion that smoking was an important cause of lung cancer. Despite supporting evidence from a similar study in the USA, they decided to test the validity of their finding. So they began another study in 1951: this was a cohort study of smoking and mortality among male British doctors. The last paper in 2004 by Doll, Richard Peto, and others, contained the results for 50 years of observation on some 35 000 participants.

Interim papers had initially confirmed the excess of lung cancer among smokers but gradually showed that smoking was associated with mortality from many other conditions including heart disease: indeed half or so of persistent cigarette smokers would die prematurely from their habit. The only encouraging indication from the study was that quitting prolonged life.

Naturally enough, Keating devotes much of his book to the origin, conduct, and impact of the main smoking study. Among the other studies that Doll pursued, the author describes those on asbestos fibres, oral contraceptives, human immunodeficiency virus, peptic ulcers, and water fluoridation. Since Doll's bibliography exceeds 500 items, Keating had a wealth of material from which to choose.

Readers of this journal are likely, however, to have a particular interest in Doll's radiation work. The greybeards among them may recall his 1957 report for the MRC with Michael Court-Brown on leukaemia in patients irradiated as treatment for the condition ankylosing spondylitis. In an interview with Sarah Darby for *Epidemiology* in 2003, Doll said that this was his second most important piece of work. Court-Brown and Doll had previewed their report in the 1956 MRC report on *The Hazards to Man of Nuclear and Allied Radiations* where they also wrote about the incidence of leukaemia among the A-bomb survivors. Keating points out that Doll's wife, Joan Faulkner, was a medical member of the MRC secretariat at the time.

In his perceptive obituary of Doll, published in these pages during 2005, Richard Wakeford mentions the disagreement between Doll and Alice Stewart, which began in 1960, about a possible association between obstetric x-rays and childhood leukaemia. Her Oxford case-control study had found an association, his cohort study not. Doll would later concede the point, but Stewart's work had been temporarily devalued and she remained embittered to the end of her life. Keating devotes an engrossing chapter to this sad affair.

A pair of papers in the *British Journal of Industrial Medicine* during 1970 may be said to have initiated the serious study of radon exposure in the UK. One, co-authored by Doll, was about radon as a possible cause of lung cancer among iron ore miners in Cumberland near Windscale. The other, about radon in mines throughout the country was co-authored by Mick Duggan of the MRC Radiological Protection Service, forerunner of the National Radiological Protection Board (NRPB). Almost three decades later, in 1998, Doll would co-author a paper in the *British Journal of Cancer* on a study of lung cancer and radon in homes conducted by ICRF and NRPB, which indicated that the risks from radon in mines and homes were comparable.

Back in 1976, Doll was one of only two medical members of the Royal Commission on Environmental Pollution when it made its sixth report, which was on nuclear power. The report had some criticisms of the fledging NRPB, one of which was that the Board membership was biased towards medicine. So there was a certain irony about the appointment of Doll as an adviser to the Board in 1986. During his appointment, which ran to 2003, he also chaired the Advisory Group on Non-Ionising Radiation. This produced several substantial documents under his stewardship especially on the risk of cancer from electromagnetic fields and ultraviolet radiation. He was greatly admired by members of NRPB staff.

Doll appeared as an expert witness in several court cases—on fluoridation, for example, as well as smoking. But Keating devotes most space to a vivid account of the Reay and Hope case in which Doll appeared for British Nuclear Fuels Limited (BNFL). This was a joint action in the High Court at London, mainly during 2003, on behalf of two children who had contracted cancer, the allegation being that the cause was the exposure of their fathers to radiation at the local BNFL Sellafield works. The plaintiffs' case was founded on the concept of paternal preconception irradiation, then current. That the action did not succeed was mainly due to Doll's testimony: the dismissal of the claim was explicitly based on the failure of the supporting epidemiological study to satisfy the Bradford Hill criteria.

This book is surely the product of much labour, and the writing is fluent. The author had Doll's full cooperation and scientific guidance from Doll's colleagues at Oxford. He interviewed some 190 relevant people and also explored the documented record. The outcome is as close to a complete biography as Doll's long life and vast work could allow.

Mike O'Riordan

IAEA Safety Standards Series No SSG-2: Deterministic Safety Analysis for Nuclear Power Plants
Vienna: IAEA (2009)
ISBN 978-92-0-113309-0 (84pp)

The IAEA has a single safety fundamentals document which is supported by a set of safety requirements documents. These in turn are supported by safety guides which can be either generic or facility/activity specific. IAEA have recently published specific safety guide SSG-2 'Deterministic Safety Analysis for Nuclear Power Plants', the full text of which is available from http://www-pub.iaea.org/MTCD/publications/PDF/Pub1428_web.pdf. SSG-2 has the objective of providing harmonized guidance to designers, operators, regulators and providers of technical support on deterministic safety analysis for nuclear power plants. Fifty-six pages of text provide recommendations and guidance on how to comply with the deterministic safety analysis requirements contained in two of IAEA's safety requirements documents, namely 'Safety of Nuclear Power Plants: Design', and 'Safety Assessment for Facilities and Activities'. It provides information on carrying out the safety analysis and the use of the results of such analysis for various purposes including safety and reliability improvements. The Safety Guide addresses conservative, best estimate and uncertainty evaluation approaches to deterministic safety analysis and is applicable to current and future designs of nuclear power plants. It is intended that this guidance on deterministic analysis will be complemented by guidance on probabilistic safety assessment; work is underway on 'Development and Application of Level 2 Probabilistic Safety Assessment for Nuclear Power Plants'. The contents of SSG-2 are: 1. Introduction; 2. Grouping of initiating events and associated transients relating to plant states; 3. Deterministic safety analysis and acceptance criteria; 4. Conservative deterministic safety analysis; 5. Best estimate plus uncertainty analysis; 6. Verification and validation of computer codes; 7. Relation of deterministic safety analysis to engineering aspects of safety and probabilistic safety analysis; 8. Application of deterministic safety analysis; 9. Source term evaluation for operational states and accident conditions and References.

Ian Robinson

Handbook of Anatomical Models for Radiation Dosimetry

X G Xu and K F Eckerman (eds)
Boca Raton, FL: CRC Press (2009)
ISBN 978-1-4200-5979-3 (757pp)

For external dosimetry there is a need to be able to translate any radiation field incident on the human body to a pattern of energy deposition in various organs and tissues. Similarly, for internal dosimetry there is a need to be able to relate emission rates of ionising radiation from source organs and tissues to energy deposition and hence dose rates in target organs and tissues. In order to perform these conversions, suitable physical or mathematical representations of the geometry and composition of the body are required. These representations are typically called phantoms.

The simplest mathematical phantoms that can be used for this purpose are individual geometrical shapes such as spheres or cylinders. However, by the 1960s, it had become possible to use combinatorial geometry techniques to build better representations of the human body by combining various simple geometrical shapes, e.g. truncated cones for the legs. It was models of this type that were used, for example, to calculate the Specific Effective Energy (SEE) values adopted in *ICRP Publication 30*.

However, such representations remained a crude approximation to the complex external and internal geometry of the human body, so, as the power of computers increased, a new class of models emerged, in which the body was explicitly represented by a grid of tiny volume elements (voxels). Individual voxel elements can have linear dimensions of the order of 1 mm or less, so the number of voxels required to characterise a human being was of the order of 10^8 to 10^9. Developing characterisation at this level of detail involved the use of CT and MRI images together with the interpretation of photographs of whole-body tissue sections from cadavers.

Application of either geometric or voxel representations of the human body in the context of radiation transport calculations is relatively straightforward, since each location in the body can be associated with an appropriate density and chemical composition. In general, this is done by assigning each voxel to an identified organ or tissue with a standardised composition. However, the voxel representation is somewhat inflexible geometrically. Thus, transforming the representation, e.g. to correspond to an individual of different height or body mass, or in a different body attitude, is difficult. This difficulty can be overcome by recognising that the key information is the two dimensional boundaries of the various organs and tissues and the overall two dimensional boundary that separates the interior of the body from the external world. Thus, in recent years, attention has been concentrated on the development of phantoms based on the boundary representation (BREP) approach. In this approach, only boundaries of objects are defined. These boundaries can be specified as smooth surfaces, e.g. by interpolation between a set of reference points in the non-uniform rational b-spline method, or by representing the surface as a set of polygons. Once boundaries have been defined, transformations in size and configuration can be achieved through automated algorithms including suitable heuristics, e.g. that when the boundary of a higher density organ such as the liver meets the boundary of a lower density organ such as the lung, the lower density organ preferentially deforms.

Although phantoms based on the BREP approach have the greatest degree of adaptability, they are not well matched to the current generation of radiation transport codes. Thus, a typical approach is to transform the anatomical data into a BREP phantom, deform that phantom to the required geometry, and then back-transform the modified phantom to a voxel-based system for radiation transport calculations.

This handbook provides a comprehensive account both of the history of phantom development and of the current state-of-the-art. Chapter 1 comprises a comprehensive historical overview both of mathematical phantoms and of physical phantoms comprised of tissue equivalent materials that provide complementary or confirmatory information. This chapter also outlines the basis of the Monte Carlo radiation transport codes used with such phantoms. One omission is an account of the mathematical basis of BREP-type phantoms, but this omission is remedied in later chapters. There then follows a series of 14 chapters on various mathematical phantoms, including those now adopted by the ICRP for dose calculation purposes. An indication of the effort that is put into generating these phantoms comes from the account of the Visible Chinese Human project in which a human cadaver was subject to CT and MRI scans before being sectioned at 0.2 mm intervals into 8920 slices. Each slice was then photographed to provide a digital colour image at 5440 × 4080 pixel resolution to give a voxel size of 0.1 × 0.1 × 0.2 mm. The power of the BREP approach is evidenced by approaches to the construction of pregnant female phantoms in which a mesh representation of the mother is deformed to accommodate mesh representations of the foetus at different stages of gestation.

The first part of the book concludes with a useful chapter on physical phantoms. Part two, which relates to applications, covers a variety of topics including calculations of dose conversion coefficients, optimum placement of multiple dosimeters for effective dose estimation, hot particle dosimetry, and dose estimation in radiopharmaceutical diagnostics and treatment, CT scanning and external beam therapy. There is also a chapter on applications to non-ionising radiation, plus a chapter on direct and indirect bioassay procedures that seems both out of place and pitched at a much more elementary level than many of the other chapters.

Throughout, the text is copiously illustrated with greyscale images and these are complemented by a set of colour plates for those images where a greyscale version is not adequate to illustrate the key information. Furthermore, there are numerous figures and tables presenting detailed data that will be of considerable interest to those working in this area.

The individual chapters are written by a wide variety of authors. However, the editors have clearly been attentive, as the readability is uniformly high and the individual chapters are complementary rather than repetitious. This is a considerable achievement, since many of the phantoms have been developed using similar techniques and even the same software tools.

In a brief review, it is impossible to do justice to the wealth of information contained in this volume (e.g. on representation of the complex spatial patterns of mineral bone, and red and yellow marrow, or the use of time-varying phantoms in medical contexts where respiratory movements and the beating of the heart need to be taken into account, as in the MCAT cardiac-torso phantom). Although primarily a work of reference, almost all the chapters can be read for pleasure and I commend this work to anyone with an interest in physiology or radiation dosimetry. This is clearly an active area of research and we can look forward to further developments, such as increased use of 4-dimensional phantoms (3-dimensional figures transforming in time, e.g. to simulate operational activities in high-radiation areas) and the development of phantoms in which heterogeneities of material properties within organs and tissues are more generally represented. Perhaps the most immediate need is to develop updated radiation transport codes that are compatible with BREP approaches, so that the inverse transformation to voxel-based representations can be avoided.

Mike Thorne