Institution: University of Salford

Unit of Assessment: 7

Title of case study: Radioactivity, environment and society: changing practice and perception

Period when the underpinning research was undertaken: November 2011 – January 2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Prof. Mike Wood	Chair in Applied Ecology	November 2011 – Present

Period when the claimed impact occurred: January 2014 – December 2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

From nuclear power to nuclear medicine, there is an international requirement to assess the impact of every permitted release of radioactive waste on people and the environment. Salford's award-winning radioecological research delivered the underpinning global science on radionuclide transfer required to undertake these assessments and ensure stakeholder confidence. This research has: (i) enabled robust regulation globally of permitted radioactive waste releases; (ii) facilitated nationally important decision making in the UK and Ukraine, including the return to productive and societal use of land abandoned following the 1986 Chernobyl accident; (iii) transformed societal understanding of radioactivity and the environment through global media coverage of the work; and (iv) built capacity and resilience in over 20 countries for organisations assessing radiological risk.

2. Underpinning research

Salford research underpins successful radiation protection of the world's environment from radioactive waste. NERC grants and industry research funding enabled Professor Wood to address the greatest source of uncertainty in radiological risk assessment: predicting radionuclide transfer to wildlife **[3.1** – **3.4]**. Internal radiation dose is estimated using transfer parameters to predict radionuclide levels in organisms. Wood's innovative transfer databases **[3.1]** and new mathematical method for deriving transfer parameters **[3.2]** significantly reduced transfer prediction uncertainty (by over three orders of magnitude).

Prior to Wood's research on radionuclide transfer to reptiles **[3.1]**, robust radiological risk assessments for this important wildlife group were not possible; assessors used data for other wildlife groups. Wood demonstrated that transfer to reptiles is different, deriving reptile-specific transfer parameters for use in regulatory assessments globally (see **4.1**).

The International Commission on Radiological Protection (ICRP) recommendations underpin radiological protection regulations in every nation that uses radioactive materials. Its 2007 recommendations introduced the requirement to assess environmental impacts, proposing a framework based on Reference Animals and Plants (RAPs). However, the lack of radionuclide transfer parameter values for many RAPs was a significant barrier to implementation. Wood's research at international 'reference sites' **[e.g. 3.3]** enabled derivation of crucial transfer parameter values for ICRP RAPs, including life stages (e.g. frog spawn) for which no previous data were available. Wood developed novel methods for filling remaining data gaps using evolutionary history and allometry **[3.4]**.

Wood's research on radionuclide transfer has been supplemented by his research on wildlife population exposure. Populations are the target of radiological protection, but population exposure assessment is challenging due to spatial and temporal variation in both radioactive

waste releases and population dynamics. Wood **[3.5]** provided the first comprehensive evaluation of spatial and temporal scales of relevance to wildlife dose assessments, establishing guidance required by regulators and industry (see **4.2**).

There is a need to demonstrate that radiation dose levels (benchmarks) used in decision making are fit-for-purpose and ensure that stakeholders can put radiation risk in context. Contradictory reports on wildlife radiation impacts in the Chernobyl Exclusion Zone have caused confusion amongst stakeholders, including the general public. Some stakeholders challenge the entire radiological protection system, citing studies reporting significant impacts at radiation dose levels below regulatory benchmarks. Wood **[3.3]** demonstrated that actual radiation doses to wildlife are orders of magnitude greater than those reported in these studies. Wood also pioneered research using motion-activated cameras **[3.6]** in Chernobyl, providing independently verifiable evidence of thriving wildlife populations and the return of top predators, such as brown bear, to this abandoned landscape (see **4.3**).

The findings from Wood's broad body of research **[including 3.1 – 3.6]** have enabled a major programme of international knowledge exchange, building capacity and resilience within both the nuclear and non-nuclear sectors in over 20 countries (see **4.4**).

Wood's key external collaborations are UK Centre for Ecology & Hydrology, University of Portsmouth and University of Stirling. Salford facilities supporting this impact include THINKlab, Makerspace, MediaCityUK and the Acoustics laboratories.

3. References to the research

3.1. IAEA, 2014. Handbook of Parameter Values for the Prediction of Radionuclide Transfer to Wildlife, *Technical Reports Series* No. 479, IAEA, Vienna. https://www-pub.iaea.org/MTCD/Publications/PDF/Trs479_web.pdf
3.2. Wood MD, Beresford NA, Howard BJ, Copplestone D, 2013. Evaluating summarised radionuclide concentration ratio datasets for wildlife, *Journal of Environmental Radioactivity* 126, pp. 314-325. https://doi.org/10.1016/j.jenvrad.2013.07.022
3.3. Beresford NA, Barnett CL, Gashschak S, Maksimenko A, Guliaichenko E, **Wood MD**, Izquierdo M, 2020. Radionuclide transfer to wildlife at a 'Reference Site' in the Chernobyl Exclusion Zone and resultant radiation exposures, *Journal of Environmental Radioactivity* 211, 105661. https://doi.org/10.1016/j.jenvrad.2018.02.007 **(REF2)**
3.4. Beresford NA, **Wood MD**, Vives I Batlle J, Yankovich TL, Bradshaw C, Willey N, 2016. Making the most of what we have: application of extrapolation approaches in radioecological wildlife transfer models, *Journal of Environmental Radioactivity* 151:2, pp. 373-386. https://doi.org/10.1016/j.jenvrad.2015.03.022
3.5. BIOPROTA (2016). Scales for Post-closure Assessment Scenarios (SPACE): Addressing spatial and temporal scales for people and wildlife in long-term safety assessments. ISBN 1891-5191. https://www2.dsa.no/filer/86ce9e3dce.pdf
3.6. Gashchak S, Gulyaichenko Y, Beresford NA, **Wood MD**, 2016. Brown bear (*Ursus arctos* L.) in the Chornobyl Exclusion Zone, *Proceedings of the Theriological School* 14, pp. 71-84. http://doi.org/10.15407/ptt2016.14.071

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For this body of research, Professor Wood received two prestigious awards: Times Higher Education Research Project of the Year (2016) and Society for Radiological Protection's Founders' Medal (2018).

4. Details of the impact

4.1. Enabled robust regulation globally

Salford's research on radionuclide transfer to wildlife increased the robustness of global safety assessments for radioactive waste releases. The Basic Safety Standards of the United Nations' International Atomic Energy Agency (UN IAEA) require radiological protection of the environment. UN IAEA evaluations of radiological assessment approaches identified radionuclide transfer as the greatest source of uncertainty. Wood's research **[3.1]**, including his international leadership of research on transfer to reptiles, '*has significantly reduced the uncertainty in wildlife dose assessment*' **[5.1]**. IAEA (2014) **[3.1]** is a UN IAEA Technical Report; these reports inform radiological protection implementation in 172 nations **[5.1]**.

Wood's research **[3.1]** was subsequently incorporated into *'the world's most widely used environmental radiological assessment tool'* **[5.2]**, enabling over 40 countries (including the 6 countries that collectively generate three quarters of the global nuclear power output) to demonstrate compliance with radiological protection standards **[5.3]**. Updated in 2014, version 1.2 of the ERICA Tool significantly improved estimations of radiation doses to wildlife based on Salford research **[5.2, 5.4]**. It also advanced radiation impact assessment for reptiles, including new capability to include freshwater reptiles within initial assessments **[5.2, 5.5]**. Reptiles dominate faunal biomass in many of the world's arid regions **[e.g. 5.2]**, are heavily protected in law (e.g. EC Habitats Directive 92/43/EEC) and are under greater conservation threat than any other wildlife group reported in the European Red List of Threatened Species. Revisions to the ERICA Tool based on Wood's research thus addressed a significant global need. The ERICA Tool is recommended by environmental regulators **[e.g. 5.2, 5.3, 5.5, 5.6]** and has been used in the permitting of radioactive waste releases from nuclear power stations, hospitals, nuclear legacy sites, offshore oil and gas production, uranium mining and research facilities **[5.2, 5.3, 5.5, 5.6]**. Wood's research thus played a key role in regulatory decision making across all these permitted activities, minimising radiological assessment uncertainty and delivering environmental protection without over-regulation (and resultant cost burdens for industry **[e.g. 5.7]**).

The Environment Agency, England's environmental regulator for the safe disposal of radioactive waste, uses Wood's research to deliver this regulatory function, which '*is vital if nuclear energy is to make a contribution to sustainable development goals'* **[5.5]**. They state that the ERICA Tool is '*an important part of our permitting process'*, providing assurance to the public and other stakeholders that '*regulatory decisions and assessments are based on sound scientific evidence*' **[5.5]**. In 2017, the Environment Agency used the ERICA Tool to assess the potential impact on the network of 349 Natura 2000 sites (protected under European and UK conservation legislation) of every permitted discharge of radioactive waste in England. '*This included detailed assessment of 603 permits and 3800 individual permit limits*' and demonstrated protection of the environment **[5.5]**. The Environment Agency also used the ERICA Tool for '*several high profile permit determinations'* including decommissioning of the Sellafield site **[5.5]**. According to the UK Government Nuclear Provision, Sellafield is home to the majority of the UK's radioactive waste legacy, poses levels of complexity and uncertainty that are unique in the global nuclear sector and has an estimated clean-up cost in excess of GBP91 billion; the assessments undertaken using the ERICA Tool have enabled this clean-up operation to continue **[5.5]**.
The primary environmental regulator in Scotland, the Scottish Environment Protection Agency (SEPA), has adopted Wood's research. According to SEPA, Wood's research on radionuclide transfer **[3.1, 3.2]** '*has significantly reduced uncertainty in dose assessments'* and is '*embedded… in our in-house radiological dose assessment tools'* **[5.6]**. SEPA staff have *'used these research outputs to undertake independent dose assessments when evaluating permit applications*' to ensure that SEPA's '*regulatory decisions are robust and based on sound underpinning research*' **[5.6]**.

Wood's research is also used by industry to inform major business decisions. For example, Magnox Ltd. is responsible for the decommissioning of 12 nuclear sites with an estimated clean-up cost of approximately GBP13 billion **[5.7]**. The Guidance on Requirements for Release from Radioactive Substances allows radioactive waste to be left on site if safety can be

demonstrated. Having '*built capacity within the…environment team*' (see **4.4**), Magnox Ltd. is minimising clean-up costs by using the ERICA Tool to demonstrate safe in-situ disposal **[5.7]**.

Wood's research **[3.1-3.4]** has also underpinned further development and practical implementation of the International Commission on Radiological Protection (ICRP) framework for radiological assessment of the environment based on Reference Animals and Plants (RAPs) **[5.8]**. The UN IAEA and every nation that uses radioactive materials base their radiological protection requirements on the ICRP's radiation protection framework. The lack of suitable transfer parameter data for many of the ICRP RAPs was a major barrier to successful application of the framework and a significant source of uncertainty. The ICRP used Wood's research, including the new mathematical approach for transfer parameter derivation **[3.2]** and studies on radionuclide transfer at 'reference sites' **[e.g. 3.3]** to provide robust transfer parameter values for the ICRP RAPs. Where data gaps remain, Wood's research on evolutionary history and allometric relationships **[3.4]** provided mechanisms for estimating appropriate transfer values. Wood's research is acknowledged to have made a '*tremendous contribution*' to the development of the ICRP RAP Framework, impacting the system of radiological protection that is adopted worldwide **[5.8]**.

4.2. Facilitated nationally important decision making

Radioactive Waste Management Ltd. is responsible for delivering the UK's Geological Disposal Facility, a multi-billion pound solution to nuclear waste management. The updated ERICA Tool, our new models **[3.4]**, and guidance on spatial and temporal scales **[3.5]** have provided Radioactive Waste Management Ltd. with tools necessary to evaluate the radiological vulnerability of the surrounding landscapes during the site selection process. They state that Wood's research is '*game changing*' and that '*the resultant reduction in radiological risk assessment uncertainty helps to ensure societal confidence in nuclear programmes'* **[5.4]**. Wood's research **[3.4, 3.5]** has directly supported safety case development for the UK's Geological Disposal Facility and provided a robust scientific basis for Radioactive Waste Management Ltd. to respond to challenges from stakeholders, such as Greenpeace and Nuclear Waste Advisory Associates **[5.4]**.

Wood's radionuclide transfer and wildlife research **[e.g. 3.3, 3.4, 3.6]** was used by the State Agency of Ukraine for Exclusion Zone Management (SAUEZM) to plan future management of approximately 4000km^2 of Chernobyl-contaminated lands abandoned after the 1986 accident. Working with stakeholders including local communities, the research has underpinned development of a protocol for Ukrainian authorities to screen abandoned land and return it to economic use. It has also informed planning for the Ukrainian Chornobyl Radiation-Ecological Biosphere Reserve, which was created in 2016 and, in conjunction with the adjoining reserve in Belarus, constitutes the largest abandoned area in Europe. Wood's research has put SAUEZM in a '*position to bring major economic benefits to Ukraine by enabling the State, local populations and business to reuse lands'* **[5.9]**.

4.3. Transformed societal understanding internationally

Wood's research **[e.g. 3.6]** reached an extensive global audience, featuring on major media outlets internationally including the BBC, Channel 4, ABC, CNN, LA Times, National Geographic, TIME, New Scientist, The Telegraph and Financial Times **[5.10]**. It also featured in a major international documentary (on BBC4-UK, SBS-Australia and PBS-USA) and an award-winning BBC documentary **[5.10]**. In 2015, the BBC cited Wood's brown bear research discovery **[3.6]** in the 'top 100 things we didn't know last year' **[5.10]**. The extensive reach of Wood's research changed public opinion, with nuclear regulators citing Wood's media coverage when reporting resultant positive change in stakeholder attitudes towards environmental radioactivity **[5.3, 5.5, 5.6]** and the Ukrainian State Agency reporting that Wood's research '*has changed perceptions of Chernobyl Exclusion Zone in Ukraine and internationally*' **[5.9]**. Wood also undertook extensive public engagement **[5.10]**, developing a virtual reality platform 'Virtual Chernobyl' to support knowledge exchange and education based on his research. Reaching approximately 10,000 people (from school children to pensioners) at science festivals and other events (2015 – 2020), visitor feedback confirmed '*changes in public opinion regarding radiation*

and its impacts' **[5.10]**. Virtual Chernobyl has introduced Wood's research into education, including in Ukraine, and supported IAEA Missions to build public communication capacity in Fukushima Prefecture (Japan) and in Thailand **[5.1]**. In 2016, Wood received the highly prestigious **Times Higher Education Research Project of the Year award** recognising the societal impact of his research which has '*hugely increased understanding of how nuclear radiation affects animal life'* **[5.10]**.

4.4. Built capacity and resilience in over 20 countries

Developing '*the capability and capacity of the nuclear regulators'* is a key element of the UK Government's Clean Growth Strategy and every nation using radioactive materials faces a similar challenge **[5.1]**. Drawing on his broad body of research **[including 3.1 – 3.6]**, Wood and colleagues have delivered regular bespoke knowledge exchange programmes for the UN IAEA and various nations, including Australia, Japan, Egypt, New Zealand and Thailand **[5.1, 5.2, 5.3]**. Attended by more than 350 people, participants report that this '*excellent interactive course*' delivered by '*the absolute experts in radiological risk assessment*' has given them '*confidence to use the ERICA Tool in practice*' **[5.3]**. Approximately 80% of respondents to a recent international survey stated that this training has changed the way in which they conduct assessments and '*allowed improved decisions to be made*' **[5.3]**.

In the UK, Wood and colleagues have trained 25 Environment Agency regulators **[5.5]** and '*nearly half of the SEPA radioactive substances team'* **[5.6]**, enabling them to apply Salford's science **[3.1 – 3.6]** within their regulatory functions. These organisations state that this has *'increased our in-house capability to undertake wildlife radiological assessments, leading to increased resilience and reduced risk to our business'* **[5.5]** and '*built our in-house resilience and capability in radiological dose assessment'* **[5.6]**.

5. Sources to corroborate the impact

5.1. Testimonial: UN IAEA (February 2021) on: (i) reducing uncertainty in radiological risk assessment and ensuring protection of reptiles (4.1); (ii) building capacity in Japan to respond to stakeholders, supported by Virtual Chernobyl (4.3); and (iii) building capacity in Thailand and Egypt to deliver successful environment protection (4.4)
5.2. Testimonial: Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) (March 2021), on the ERICA Tool development using Salford radionuclide transfer research (4.1) and its application in national decision making for major projects
5.3. Participant feedback on effectiveness of the ERICA course for building capacity and organisation resilience and international survey demonstrating subsequent impacts (4.4)
5.4. Testimonial: Radioactive Waste Management Ltd. (February 2021), on ensuring safe management of radioactive waste (4.1), informing decision making on the UK's Geological Disposal Facility and providing the robust science for responding to stakeholder challenges (4.2)
5.5. Testimonial: Environment Agency (December 2020), on radioactive waste regulation and management (4.1), changing perceptions (4.3), building capacity and business resilience (4.4)
5.6. Testimonial: Scottish Environment Protection Agency (February 2021), on use of the ERICA Tool for dose assessments (4.1) and capacity building and business resilience (4.4)
5.7. Testimonial: Magnox Ltd. (March 2021), on informing selection of long-term waste disposal options (4.1) and extent of capacity built and reduction in business risk (4.4)
5.8. Testimonial: International Commission on Radiological Protection (March 2021), on contribution to international framework for environmental radiological protection (4.1)
5.9. Testimonial: State Agency of Ukraine on Exclusion Zone Management (May 2018), on planning the management and return to society of Chernobyl abandoned lands in Ukraine (4000km^2) (4.2) and the role of Wood's engagement activities in changing perceptions (4.3)
5.10. Significance and reach of media activity and direct public engagement demonstrated by: (i) Testimonial: Director, Manchester Science Festival (May 2018), on public engagement and contribution to improving societal understanding of radioactivity; (ii) the BBC's 2015 statement on one of the 'top 100 things we didn't know last year'; (iii) examples of international media reports on our Chernobyl research; (iv) awards for documentaries featuring this research; and (v) the citation for our Times Higher Education Research Project of the Year Award (4.3)