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Abstract

Between 1940 and 1955, Britain explored controversial radiological weapons. Keen to discover further military uses for atomic energy, defence officials and scientists initially approached the field with much hope and optimism. However, technical difficulties, economic costs, public and political aversion, competition from other controversial weapons, and even the resistance of scientists themselves, soon came to dominate the direction of policy. This article explores the unique British experience with radiological weapons, determines how far Britain ventured down this questionable path, and accounts for why, after over a decade of research, they were judged a step too far.

Keywords

radiological warfare, atomic energy, secret science, Second World War, Cold War, United Kingdom

The use of radioactive material in a large-scale military role, for anything other than a nuclear bomb, may at first appear to be a relatively strange concept. Why settle for simply dispersing radioactive material, when you could use it to create a substantial explosive device? During the Second World War and early Cold War, though, this is exactly what British researchers investigated. Nuclear weapons dominated British thinking in the field of nuclear physics, but research into radiological warfare (RW) proceeded concurrently, and with great hope over the possibilities these new weapons represented. Scientists exploring this controversial avenue were also not operating separately from those researching the atomic bomb; they were often the very same people. Among those

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to explore and address RW were Otto Frisch, Alan Nunn May, James Chadwick, William Marley and Sir John Cockcroft.

The history of nuclear weapons and nuclear planning has attracted substantial academic literature; however, the use of radioactive material for weapons other than an atomic bomb has received comparatively scant attention. In 1985, Barton Bernstein published an insightful article titled 'Radiological warfare: the path not taken', where he examined Anglo-American RW research.¹ While a crucial intervention, Bernstein's account did not have the benefits of archival releases and as such misses the extent of British interest in RW, the roles of key scientists, RW planning and much of the post-war period. Scholars in the United States have followed up on his foundational work, yet there remains next to nothing on Britain's experience.² In addressing this gap, the article will also be building on Margaret Gowing's seminal works on British nuclear history, which intimated that this controversial avenue of British research existed but which did not explore it.³ Exploration of RW represents an important and untold segment of British history.

The British RW experience is not an isolated field, but one which can further enrich and enhance our understanding of British nuclear history. At its core, it represents an extremely questionable form of warfare and essentially the worst after-effects of a nuclear bomb, that of radiation sickness and potentially prolonged suffering, and deliberately weaponizes them for military use. The British encounter with RW reveals the extent defence officials were willing to go in seeking new weapons for the Second World War and Cold War, as well as the influence of scientists and the impact of public anxiety. By using previously untapped archival sources, this article will fill a significant gap in our understanding of British military history.⁴ It will not confine itself solely to the views of defence officials, but include the perspectives of scientists, politicians and the public, and consider the contrasting approach taken by the United States. Ultimately, it will reveal Britain's unique approach to RW, assess how far the country ventured down this controversial path, and account for why, after 15 years, radiological weapons were unequivocally dismissed.

1 Barton Bernstein, 'Radiological Warfare: The Path Not Taken', *Bulletin of the Atomic Scientists*, 41:7 (1985), pp. 44–9.

2 See for example: Adri De La Bruheze, 'Radiological Weapons and Radioactive Waste in the United States: Insiders' and Outsiders' Views, 1941–1955', *The British Society for the History of Science*, 25:2 (1992), pp. 207–27; Sean Malloy, "'A Very Pleasant Way to Die": Radiation Effects and the Decision to Use the Atomic Bomb against Japan', *Journal of Diplomatic History*, 36:3 (2012), pp. 515–45; Lisa Martino-Taylor, *Behind the Fog: How the U.S. Cold War Radiological Weapons Program Exposed Innocent Americans* (Oxon: Routledge, 2017).

3 See in particular: Margaret Gowing, *Britain and Atomic Energy 1939-1945* (Hampshire: Palgrave Macmillan, 1964), pp.103–4, 384, 392–3.

4 This article has benefitted from files on UK RW research found at: The National Archives - UK (herein abbreviated to TNA), AB 1/411 and AB 1/608 (for wartime research), AB 15/769, AB 15/1773, AB 16/1585 and DEFE 32/3. It has also used newspaper sources, for example from *The Times*, *The Manchester Guardian*, the *Daily Express*, the *Daily Mail*, as well as political debates and coverage from Hansard.

It should also be noted here that this article takes a radiological weapon to mean: *Any device, other than a nuclear explosive, specifically designed to employ radioactive material, by disseminating it to cause destruction, damage, or injury, by means of the radiation produced by the decay of such material.*⁵ As such, facets like the ‘cobalt bomb’—a nuclear weapon with cobalt metal packed around it to maximize radioactive fallout after detonation, have not been included.⁶

A new weapon

In March 1940, Otto Frisch and Rudolf Peierls, exiles from Germany working at Birmingham University, examined the potential applications of Uranium-235. Noting that Uranium-235 could be used for a ‘super bomb’, they detailed the yield and possible destructive effects of radiation and nuclear fallout from such a weapon.⁷ But, they also alluded to the possibility of a radiological weapon. Both believed that a Uranium-235 bomb would produce strong radiations, which could be carried by the wind to contaminate a large area and inflict significant numbers of casualties.⁸

Building on the advice of Frisch and Peierls in exploring the feasibility of an atomic bomb, in July 1941 the MAUD Committee, a scientific working group, produced reports justifying the necessity of Britain attaining atomic weapons.⁹ It included highly influential and notable scientists such as James Chadwick, John Cockcroft and Patrick Blackett.¹⁰ The Committee’s recommendations would lead to the creation of Tube Alloys, Britain’s atomic weapons programme.¹¹ Although the findings of the MAUD Committee are central to the history of British nuclear weapons, they are also to the history of British engagement with RW.

The interest in radiations was not present in the MAUD Committee reports recommending the development of nuclear weapons, but in the criticism of them. The Defence Services Panel, chaired by Lord Hankey and of the Scientific Advisory Committee, was initially tasked with reviewing the findings of the MAUD Committee.¹² After questioning

5 Joseph Rotblat, *Nuclear Radiation in Warfare* (London: Taylor & Francis, 1981), p. 131.

6 After detonation highly radioactive Cobalt-60 would be released to contaminate a wide area. Informed and accurate analysis of this aspect would also be immensely difficult given the recent withdrawal of hundreds of files on atomic history from TNA, which included later coverage of the cobalt bomb.

7 ‘The Frisch-Peierls Memorandum’, Found in: Robert Serber, *The Los Alamos Primer: The First Lectures on How to Build an Atomic Bomb* (London: University of California Press, 1992), pp. 80–1; Christoph Laucht, *Elemental Germans: Klaus Fuchs, Rudolf Peierls and the Making of British Nuclear Culture 1939-59* (Hampshire: Palgrave Macmillan, 2002), pp. 38–41; Malloy, “‘A Very Pleasant Way to Die’”, p. 520.

8 Serber, *The Los Alamos Primer*, pp. 81–3.

9 TNA, CAB 90/8, ‘Utilisation of the Atomic Energy in Uranium’, Not by the secretary of the Defence Services Panel, 27 August 1941, attached reports by the M.A.U.D. Committee; Matthew Jones, *UK Strategic Nuclear Deterrent, Volume I: From the V-Bomber Era to the Arrival of Polaris, 1945–1964* (Oxon: Routledge, 2017), p. 1.

10 Gowing, *Britain and Atomic Energy*, p. 97.

11 Laucht, *Elemental Germans*, pp. 47–50.

12 TNA, CAB 90/8, ‘M.A.U.D. Report’, Defence Services Panel, 24 September 1941.

some of the MAUD Committee members, one of the Panel's key criticisms was that they focused too heavily on the prospects of an atomic bomb at the expense of other potential areas of weapons development.¹³ Cautioning that it may be 'possible to develop a process for producing by other means the by-products resulting from the [atomic] explosion.'¹⁴ The Panel discussed the impact of radioactive dust particles released from the bomb, considered the potentials of radiological weapons, and encouraged more attention be paid to the lethal effects of radioactivity. Importantly, it pushed for further research on the alternative uses of atomic energy for weapons, despite the reservations of Blackett and the doubts of the other physicists who gave evidence.¹⁵ The Defence Services Panel thus invited the MAUD Committee to work and cooperate with both the Medical Research Council and Porton Down, Britain's principal chemical and biological warfare (CBW) research establishment, in investigating the range and extent of the radioactive effects of the bomb explosion and the feasibility of obtaining such effects by the gradual release of the energy.¹⁶

One British scientist to build upon the queries of the Defence Services Panel and the Frisch and Peierls' memorandum was none other than Alan Nunn May. Later revealed as one of the Soviet atom bomb spies, May passed atomic secrets to the Soviet Union from 1941.¹⁷ Under the supervision of James Chadwick, in the 1930s May was a PhD researcher at the Cavendish Laboratory for experimental physics in Cambridge. In April 1942, he joined the group of scientists working on atomic weapons for the Department of Science and Industrial Research at the Cavendish Laboratory.¹⁸

Within a few months of joining, May was asked to review a US report that warned Nazi Germany was planning the creation of radiological weapons.¹⁹ After reading this US report, shared through close Anglo-American cooperation in the emerging atomic energy field, May warned his Soviet handlers of a potential German 'dirty bomb' using radioactive material.²⁰ The Soviets, though, 'were not very impressed by this warning.'²¹ Alongside passing this information to his Soviet handlers, he also wrote a report for British officials. Circulated in August 1942, May studied the potentials and possibilities of RW.²² The report was one of the first of its kind for British assessments of radiological weapons. May explored the utility of 'Radioactive Poisons', the dosage of radiation

13 CAB 90/8, 'M.A.U.D. Report', Defence Services Panel, 24 September 1941.

14 TNA, CAB 90/8, Minutes of 10th Meeting, Defence Services Panel, 3 September 1941.

15 TNA, CAB 90/8, Minutes of 13th Meeting, Defence Services Panel, 19 September 1941; Gowing, *Britain and Atomic Energy*, p. 104.

16 TNA, CAB 90/8, Minutes of 13th Meeting; Gowing, *Britain and Atomic Energy*, p. 104.

17 Richard Aldrich and Rory Cormac, *The Black Door: Spies, Secret Intelligence and British Prime Ministers* (London: William Collins, 2016), p. 142.

18 Andrew Brown, 'The Viennese Connection: Engelbert Broda, Alan Nunn May and Atomic Espionage', *Intelligence and National Security*, 24:2 (2009), p. 179.

19 Brown, 'The Viennese Connection', pp. 189-90.

20 Chris Hastings, 'Deathbed Confession of Spy Who Betrayed Atom Bomb Secrets', *The Telegraph*, 26 January 2003, <https://www.telegraph.co.uk/news/uknews/1420088/Deathbed-confession-of-spy-who-betrayed-atom-bomb-secrets.html>.

21 Hastings, 'Deathbed Confession of Spy Who Betrayed Atom Bomb Secrets'.

22 TNA, AB 4/130, 'Radioactive Poisons', Alan Nunn May, 19 August 1942.

necessary to prove fatal, the effects of successive doses and long exposure, problems involving transportation, and the precautions necessary for handling radioactive material for military purposes. While this early foray into the RW field reveals attempts to seek alternative uses of fissionable material for military purposes, it also revealed a severe absence of reliable scientific data; May's initial findings were tentative and vague.

May's report also highlighted the degree of British reliance on growing United States activity in the field. May was not only inspired by US reports, but he also drew heavily upon US scientists when forming his assessment. Scientists in the United States had been far more active in the RW field than their British counterparts. In May 1941, United States Nobel physicist Arthur Compton proposed that the United States should develop radiological weapons for use against its enemies.²³ Building on this was a report by Eugene Wigner, a theoretical physicist and key figure in the Manhattan Project, which considered in detail the potential applications of radiological weapons against civilians and soldiers.²⁴ Noted for being 'exceedingly vicious' in nature, his report was deemed to cross the moral threshold into barbarity.²⁵ Parts of this hugely controversial report by Wigner were used by May, in his tentative assessment of radiological weapons.²⁶

Although Tube Alloys, Britain's atomic weapons research programme, focused almost entirely on the atom bomb project, in view of United States research and growing domestic scientific interest it also considered the possibilities of radiological weapons.²⁷ In mid-1943, as the Second World War raged and research towards the atomic bomb appeared to be struggling, officials at Tube Alloys addressed in detail the potential military applications of radioactive fission products.²⁸ In terms of delivering radiological weapons, difficulties with aerial delivery, such as protecting pilots from radiation exposure and ensuring that radioactive dust covered a wide area, were thought problematic, but not insurmountable. The main issue for scientists at Tube Alloys was that of dosage levels and the effects of radiation exposure on humans. In the short-term, a small dosage of radiation could lead to feelings of nausea and depression, but a large dosage could lead to sterility and death. Lethal exposure would depend on the time spent in the contaminated area, which could be upwards of 1–2 weeks. A radiological weapon requires this period of extended exposure to enable the build-up of radioactive material in the body to reach fatal levels.²⁹

The delay in causing fatalities was thought to bring about potential military, and even political, advantages. This time-lag, between weapon use and the gradual build-up of radiation to lethal levels in the human body, was deemed a particularly beneficial aspect of using

23 Bernstein, 'Radiological Warfare', 44–5.

24 Andrew Szanton, *The Recollections of Eugene P. Wigner as Told to Andrew Szanton* (Cambridge, MA: Basic Books, 2003), pp. vii–ix.

25 Bernstein, 'Radiological Warfare', pp. 44–5.

26 TNA, AB 4/130, 'Radioactive Poisons', Alan Nunn May, 19 August 1942.

27 This was as a result of May's report, the earlier Defence Services Panel request and ongoing provisional research at Porton Down and the MRC.

28 TNA, AB 1/608, 'Memorandum on the Use of Radio-Active Fission Products as a Military Weapon', Directorate of Tube Alloys, 30 August 1943.

29 TNA, AB 1/608, 'Memorandum on the Use of Radio-Active Fission Products as a Military Weapon'.

radiological weapons over other weapons with a more immediate effect, such as conventional or chemical weapons. Officials from Tube Alloys observed that 'no great harm would befall the population provided that the radiation was quickly detected and the evacuation expeditiously carried out'.³⁰ Radiological weapons could therefore temporarily hamper an enemy's war effort by causing the mass-evacuation of crucial areas, for example, industrial centres or key defensive locations, without immediately inflicting large numbers of casualties on a scale comparable to other methods of warfare. This fundamental distinction seemed to reveal a clear military role for radiological weapons. By not causing immediate casualties, and through providing civilians with the opportunity to flee contaminated areas before exposure proved fatal, officials at Tube Alloys were attempting to draw a clear moral line between the use of radiological weapons and other weapons. This attempt to humanize, or at the very least rationalize and justify the deliberate exposure of civilians to harmful radiations, though, gave little attention to the long-term effects of such a weapon. The perceived beneficial delayed effect of radiological weapons thus remained an early driver, and source of some promise, for increasing British interest.

An integral part of early research into RW, which had strong ties to broader atomic weapons research, was measuring the effects of radiation on humans. Initially, this research was theoretical, but in the early 1940s it branched out into a growing body of laboratory research.³¹ In the United States, Joseph Hamilton investigated the effects of fission products on the human body. In addition to testing on animals, he also injected hospital patients, who were not consulted, with radioactive tracers and then monitored their health.³² Hamilton passed his ethically questionable research on to British experts.³³ Officials in both countries, however, found it troublesome to investigate the effects of fission products on humans due to difficulties in acquiring suitable radioactive material and, unsurprisingly, willing test subjects.

While some scientists conducted small-scale human experiments, others, such as Louis Hempelmann and Albert Thelwall Jones, used their positions as medical personnel in their respective country's nuclear weapons programmes to collect information on radiation exposure.³⁴ In the United States, Hempelmann conducted numerous tests on workers and researchers who were accidentally exposed to radioactive material when working on the nuclear weapons programme.³⁵ British scientists, on a much smaller scale, also used the accidental exposure of workers to understand the effects of radiation on the human body.³⁶ One example of this was seen when a worker by the name of T.K. Woods died of a brain haemorrhage in early 1944. While Woods' widow explored the

30 TNA, AB 1/608, 'Memorandum on the Use of Radio-Active Fission Products as a Military Weapon'.

31 Malloy, "'A Very Pleasant Way to Die'", pp. 523, 526.

32 Martino-Taylor, *Behind the Fog*, pp. 13-4, 29-30.

33 TNA, AB 1/411, 'Clinical Effects of Fission Products', J. Chadwick to W. Akers, 13 December 1944.

34 For the US see: Martino-Taylor, *Behind the Fog*, pp. 13-5. For the UK see: TNA, AB 1/413, letter to W. Akers from Thelwall Jones, 6 November 1945.

35 Martino-Taylor, *Behind the Fog*, pp. 13-4.

36 TNA, AB 1/413, Thelwall Jones to W. Akers, 6 November 1945.

option of special compensation for the mysterious death of her husband, Thelwall Jones and a colleague used the opening to test Woods' brain and organs for the levels and effects of radiation exposure.³⁷ Initial tests on Woods' brain indicated a relatively high level of radiation, but this was judged just to be 'a very unfortunate coincidence'.³⁸ Keen to further understand the effects of radiation on the human body, British researchers deemed it hugely important to have every scrap of available information on the medical effects of radiation. This was seemingly regardless as to whether it was from hugely controversial information supplied by US scientists, or from their own research findings and autopsies on deceased staff members.³⁹

Reflective of the desire to attain further information, James Chadwick, an instrumental scientist in Britain's nuclear weapons research and Nobel Prize winner for the discovery of the neutron, also enquired in the United States as to the effects of radiation on the human body.⁴⁰ Chadwick first approached General Leslie Groves, head of the atom bomb project at Los Alamos, who in turn recommended Hempelmann. In April 1944, based on access to Hempelmann's findings on some 20–25 cases of human over-exposure to radiation, Chadwick ruefully noted that on the whole 'information on the effects of radiation on T.A. [Tube Alloys] personnel is so far very meagre'.⁴¹ While recommending stringent protective measures for Tube Alloys personnel, he urged for greater research on the effects of radiation, especially on the dangers of inhalation or ingestion of fission products into the body. Chadwick also briefly addressed precautions against the use of fission products by an enemy as a military weapon. If used against the civilian population, he summarised the views of British and US scientists, in stating that

Opinion here coincides with the conclusions reached in England, that the chief thing to do is to map out the areas of infection by means of radiation meters . . . and to evacuate those areas in which the intensity reaches the dangerous limit.⁴²

During the latter stages of the Second World War, it was increasingly clear that interest in the potential of RW was being pursued at very different rates between the Anglo-American partners. In the United States, adding to the views of scientists such as Compton, Wigner and Hempelmann, Stafford Warren, an expert in nuclear medicine, concluded in 1943 that fission products could indeed prove an effective military weapon.⁴³ That same year, reflecting the emerging promise surrounding radiological weapons, the United States established the Radiological Weapons Experimentation

37 TNA, AB 1/411, 'Arrivals of a Brain Sample', Letter to J. Ferguson, 20 July 1944.

38 TNA, AB 1/411, 'Tube Alloys – Health Hazards', Letter to J. Gillbert, 12 April 1944.

39 I TNA, AB 1/411, 'Tube Alloys – Health Hazards'. Rather than directly gathering information for RW, much of this research tied into wider analysis of the after-effects of an atomic bomb.

40 TNA, CAB 126/332, J. Chadwick to J. Anderson, 29 April 1944; Margaret Gowing, 'James Chadwick and the Atomic Bomb', *Royal Society*, 47:1 (1993), p. 83.

41 TNA, CAB 126/332, J. Chadwick to J. Anderson, 29 April 1944.

42 TNA, CAB 126/332, J. Chadwick to J. Anderson.

43 Malloy, "'A Pleasant Way to Die'", p. 526.

Group, which was responsible for conducting research and development in the RW field.⁴⁴ Conversely, British assessments of the radiological weapons, despite recognizing the potentials, were far more tentative.

The contrasting expenditure of effort and resources in the RW field, as well as close Anglo-American cooperation, was also revealed in perceptions of the German RW threat. From 1943, US officials had grown increasingly concerned, whereas in Britain, which was a primary target for a potential German RW attack, the threat was taken rather less seriously.⁴⁵ One sceptical British official even noted that

The Americans are more anxious about this [radiological warfare] than we are, because we believe that H.E. [High Explosives] or incendiary or mustard gas all form more lethal bomb loads than fission products . . . the Americans have never experienced a raid on a town, and therefore are horrified at the possibility of a few hundred civilians being killed.⁴⁶

In Britain and the United States, military planners had increasingly become de-sensitized to bombing, which in turn had an impact on perceptions of radiological weapons.⁴⁷ Although this one key difference did emerge in RW: British officials viewed RW as just one more obstacle in the war and not as an exceptional or unique threat, in contrast to scientists and defence officials in the United States.

Fears of potential German radiological weapons continued as D-Day approached, but were reduced when intelligence reports revealed that Germany did not possess an operational nuclear reactor.⁴⁸ Without a reactor producing radioactive material, the large-scale use of radioactive material in weapons would have been highly unlikely. Despite intelligence reports indicating it improbable, erring on the side of caution, US officials requested that defensive measures be taken in preparation for the D-Day landings. A key advocate of this was General Leslie Groves, who was concerned that Germany might use a radioactive barrier along the D-Day invasion routes.⁴⁹ General Dwight D. Eisenhower was thus informed of the RW threat, and although British officials were more sceptical, they agreed to inform senior figures such as Major General Sir Hastings Ismay of the need for defensive preparations and a working portable detector.⁵⁰ As a result, Operation Peppermint was born. The plan, never put into action, catered for the detection of

44 Martino-Taylor, *Behind the Fog*, p. 4.

45 TNA, AB 1/608, Extract from letter by Mr. Akers, 22 July 1943.

46 TNA, AB 1/608, Extract from letter by Mr. Akers.

47 See: Laucht, *Elemental Germans*, 38-41; Michael Burleigh, *Moral Combat: A History of World War II* (London: Harper Press, 2010), pp. 514-5; Spencer R. Weart, *Nuclear Fear: A History of Images* (Harvard, MA: Harvard University Press, 1988), p. 49.

48 Leonard Beaton, 'II Poor Man's Nuclear War?', *Survival*, 6:4 (1964), p. 166.

49 TNA, AB 1/608, Field Marshall Dill and Sir Ronald Campbell to Sir John Anderson, 10 January 1944; General Leslie Groves, *Now It Can Be Told: The Story of the Manhattan Project* (Cambridge, MA: Da Capo Press, 1983), p. 199.

50 TNA, AB 1/608, 'Possible Use of Radio-Active Products as Military Weapon', J.A. to General Ismay, 7 January 1944. Also see: TNA, AB 1/608, Air Ministry to JSM Washington, 6 January 1944.

radiological weapons, the treatment of soldiers, and the handling of contaminated radioactive areas.⁵¹

In the closing stages of the war, the perceived threat of German RW use continued to ebb. In March 1945, one final alarmist report came from the United States OSS, the forerunner to the Central Intelligence Agency (CIA), reporting on Hitler's potential use of 'Desperation Weapons'.⁵² These included chemical weapons, freeze weapons, an 'Atom Smasher', and a uranium bomb, which a captured German *Oberleutnant* warned would 'destroy England in one blow'.⁵³ Fears of potential German radiological weapons, though, proved unfounded. Allied investigatory teams uncovered little German interest in the RW field.

During the war, Frisch and Peierls, May, officials at Tube Alloys and Chadwick all touched upon the issue of radioactivity in humans and the weaponizing of fissionable material, but much remained unexplored. Early British engagement in the RW field was hampered by a lack of scientific data on the effects of radiation on the human body, the dominance of the atomic weapons programme, and the early scepticism of scientists. However, as the war ended in Europe, the attention of those interested in the military effects and possibilities of radiation rapidly, and dramatically, turned to East-Asia.

Marley's interventions

In August 1945, after the dropping of atomic bombs on Hiroshima and Nagasaki, US scientists arrived to gather information on the impact and effects of radiation on humans.⁵⁴ The bombs caused over a hundred thousand deaths initially, but many also died from radiation poisoning.⁵⁵ Though the radiation effects from the blast and fallout were widespread, US officials attempted to suppress any information on it.⁵⁶ Groves, in particular, feared that comparisons could be made between the after-effects of an atomic bomb and CBW.⁵⁷ Radiations from an atomic explosion were potentially deadly, invisible, and killed indiscriminately. Death from radiation poisoning would appear, in the public eye, as markedly similar to death from CBW. In November 1945, to tackle the negative image

51 For examples, see: TNA, AB 1/608, W. Akers to Michael Perrin, 27 September 1943; TNA, AB 1/608, Otto Frisch to Michael Perrin, 6 September 1943; TNA, AB 1/608, 'Portable Detectors', Letter for Gorell Barnes, 9 June 1944; TNA, AB 1/608, 'V. Weapons. Possible Use of Fission Products', M. Perrin to the Chancellor of the Exchequer, 19 September 1944. Another form of detection was through the monitoring of camera film on the front line.

52 The National Archives at College Park, MD (herein abbreviated to NARA), RG 226, Entry NM-54 16, Container 1406, 'PW Intelligence Bulletin', 13 March 1945.

53 NARA), RG 226, Entry NM-54 16, Container 1406, 'PW Intelligence Bulletin'.

54 Martino-Taylor, *Behind the Fog*, p. 64.

55 Weart, *Nuclear Fear*, pp. 58-60; Janet Brodie, 'Radiation Secrecy and Censorship after Hiroshima and Nagasaki', *Journal of Social History*, 48:4 (2015), p. 842.

56 Weart, *Nuclear Fear*, pp. 58-60; Brodie, 'Radiation Secrecy and Censorship after Hiroshima and Nagasaki', 852-4.

57 Weart, *Nuclear Fear*, pp. 58-60; Brodie, 'Radiation Secrecy and Censorship after Hiroshima and Nagasaki'.

and downplay fears, Groves testified before a Senate Committee that death from radiation exposure was actually ‘a very pleasant way to die’.⁵⁸

In Britain, there was similarly a relative lack of information on the effects of radiation. Public understanding of the longer-term consequences of radioactive material released from an atomic bomb, and by extension the use of radioactive material in a weapon, remained threadbare. Just days after the dropping of the second atomic bomb on Nagasaki, the War Office attempted to moderate public fears over radioactive products disseminated from an atomic explosion, stating that these were simply ‘dispersed harmlessly over a wide area’.⁵⁹ Only the odd breakthrough was seen, with rare reports concerning an ‘atomic plague’ or an ‘atomic bomb disease’.⁶⁰ This relative absence of information remained the case even after the publishing and release of the ‘The Effects of the Atomic Bombs at Hiroshima and Nagasaki’ by the British Mission to Japan in mid-1946.⁶¹ The report, made possible by extensive information supplied by US authorities was the result of a month-long study conducted by British officials.⁶² As a result of the only limited information available on the long-term effects of radiation exposure, both domestically and from Japan, it focused on the immediate impact of the bomb and short-term gamma radiations. Though it represented crucial information on the aftermath of an atomic bomb reaching the public domain, it included little on the issue of fallout and the dispersal of radioactive material. Dramatic and distressing images and stories were taken from the report and printed in British newspapers, such as accounts of widespread miscarriages and tens of thousands of deaths, but residual radioactivity was dubbed ‘not a danger’ and fission products falling on cities ‘insignificant’.⁶³

Alongside these accounts, public information on the first of the Bikini Atoll atomic bomb trials was also slowly emerging in July 1946, as were stories of US experts collecting samples from radioactive fallout.⁶⁴ Reflecting on these early trials, Professor Mark Oliphant, who was heavily involved in both Tube Alloys and the Manhattan Project, alarmingly stated that ‘the deaths caused by radiation from the bombs were enough to place it . . . on the list of things to be banned by civilized man’.⁶⁵ Oliphant compared these radiations to poison gas. Public awareness was also slightly aided by the limited attention afforded to the subject in Parliament. In October, Lord Cherwell, Churchill’s close scientific adviser, claimed that radioactive products from an atomic bomb

58 Malloy, “‘A Very Pleasant Way to Die’”, p. 518.

59 *The Times*, ‘New Bomb Detonated in the Air’, 13 August 1945, p. 3.

60 Adrian Bingham, “‘The Monster’? The British Popular Press and Nuclear Culture, 1945–Early 1960s.” *The British Journal for the History of Science*, 45:4 (2012), pp. 613–4; Weart, *Nuclear Fear*, 58–60.

61 Report of the British Mission to Japan, *The Effects of Atomic Bombs at Hiroshima and Nagasaki* (London: His Majesty’s Stationary Office, 1946).

62 TNA, CAB 120/842, ‘The Effects of the Atomic Bombs at Hiroshima and Nagasaki’, D. C. Stapleton to Mr Addis, [undated] 1946.

63 Report of the British Mission to Japan, *The Effects of Atomic Bombs*, 15; *The Times*, ‘Effects of Two Atom Bombs’, 1 July 1946, p. 3; *The Manchester Guardian*, ‘Devastating Effects of Atomic Bombs’, 1 July 1946, p. 3.

64 *The Times*, ‘70 Vessels as Target’, 1 July 1946, pp. 4, 6.

65 *The Times*, ‘Professor’s Report on Bikini’, 23 July 1946, p. 6.

exploding could 'poison the whole neighbourhood'.⁶⁶ And, MPs warned that the Soviet Union might use this 'radioactive dust' as a weapon of war.⁶⁷

Limited public information was in part due to strict secrecy, but it was also shaped by scientists and government officials not fully comprehending the effects of radiation and the possibilities of radiological weapons themselves. The public was in the dark, but so too were many British scientists.

In January 1946, tentative assessments by the Atomic Weapons Sub-Committee of the Deputy Chiefs of Staff Committee noted that RW might be an 'unprofitable' avenue of weapons development, either as a radioactive gas or for dispersal over the ground.⁶⁸ This was due to two perceived disadvantages: they could not be stock-piled for an extended duration due to decay, and considerable shielding would be necessary during handling.⁶⁹ Despite this scepticism, doubt remained, and a thorough investigation was needed.⁷⁰ When updating the British Chiefs of Staff Committee (CoS) on the Bikini Atoll trials, in March 1947, Sir Henry Tizard acknowledged this absence of information when he reported that 'it would be some time before sufficiently reliable scientific information was available to examine the effects of radiological warfare'.⁷¹ A lack of reliable scientific data on the effects of radiation on humans meant that British post-war engagement with radiological weapons got off to a slow start.

Keen to remedy this deficiency and after providing assurances that he would keep the CoS apprised of the RW field, Tizard did not remain idle. Central to British RW research was the establishment of the Sub-Committee on Strategic Aspects of Atomic Energy, a sub-committee of the Defence Research Policy Committee (DRPC), in 1947.⁷² Under Tizard's chairmanship, in March 1948, the sub-committee assessed the possible military uses and effects of atomic energy, which included 'radioactive poisons'.⁷³ It found that radioactive material could be used as a weapon in the Cold War and that such a weapon could contaminate the ground, the air as radioactive dust or gas, and drinking water to poison the civilian population fatally.⁷⁴ Concepts of RW use had thus moved far beyond a simple 'dirty-bomb', and they increasingly mirrored delivery methods seen in the

66 Hansard, House of Lords, 'Atomic Energy Bill', 23 October 1946, vol. 143, p. cc569–90.

67 For examples, see: Hansard, House of Commons, 'Atomic Energy Bill', 8 October 1946, vol. 427, p. cc43–98; Hansard, House of Commons, 'Clause 2 (General Powers of Minister)', 11 October 1946, vol. 427, p. cc497–508.

68 TNA, CAB 82/26, 'Matters of Fact Relating to Atomic Energy', Note by the Joint Secretaries of the Atomic Weapons Sub-Committee, 30 January 1946, Annex.

69 TNA, CAB 82/26, 'Matters of Fact Relating to Atomic Energy'.

70 The MRC also continued to advise on protections against radiations, see: TNA, CAB 126/240, D. H. Rickett to E. V. Appleton, 28 February 1946.

71 TNA, DEFE 4/3, Minutes of Meeting, Chiefs of Staff Committee, 24 Mar. 1947. Tizard did however support a Radiological Safety Committee.

72 For more on the DRPC see: Jon Agar and Brian Balmer, 'British Scientists and the Cold War: The Defence Research Policy Committee and Information Networks, 1947–1963', *Historical Studies in the Physical and Biological Sciences*, 28:2 (1998), pp. 209–52.

73 TNA, DEFE 7/908, 'Report on the Strategic Aspects of Atomic Energy', Sub-Committee on the Strategic Aspects of Atomic Energy, 22 March 1948, Attached report.

74 TNA, DEFE 7/908, 'Report on the Strategic Aspects of Atomic Energy'.

CBW field. In October 1948, the DRPC assigned high importance to researching defences against radioactive contamination, the effects of gamma radiation and the ingestion of radioactive substances.⁷⁵

In tandem with analysis as to the offensive potential of radiological weapons, scientific efforts were also underway to try and better understand the effects of radiation on humans. From 1947, the British Medical Research Council began to take a keener interest in the field, and it established a laboratory at Harwell, the location of Britain's Atomic Energy Research Establishment, to investigate the effects of radiation on living tissue.⁷⁶

This post-war British effort, however, still paled in comparison to the United States, which had the support of crucial proponents such as J. Robert Oppenheimer and James Conant, who supported the diversification of weapons research.⁷⁷ United States defence officials also believed that 'the potential value of radiological weapons may exceed that of chemical weapons'.⁷⁸ Conversely, in Britain, radiological weapons had not reached the same heights in defence planning, nor attracted the same degree of support. Radiological weapons were often omitted from assessments of weapons of mass destruction (WMDs) and 'special weapons'.⁷⁹ This was despite, in August 1948, the UN recognizing 'radio-active material weapons' as a WMD.⁸⁰ Greater United States activity in the field, the search for more scientific data and the possibility of discovering a new form of warfare did, though, serve to sustain British interest in radiological weapons.

Tentative British engagement was to be significantly influenced with the arrival of a crucial scientist, who would go on to dominate British assessments of radiological weapons. In 1949, Dr William G. Marley, OBE, built upon early British analysis and became Britain's leading authority.⁸¹ A physicist based at Harwell, he was known for being a

75 TNA, DEFE 10/23, 'Annual Review of Future Defence Research and Development Policy: October 1948', Defence Research Policy Committee, 19 October 1948.

76 TNA, DEFE 9/1, H.T.T. to A. Thomson, 16 April 1947; TNA, DEFE 9/1, Viscount Portal of Hungerford to General Hollis, 26 March 1947.

77 Greta Jones, 'The Mushroom-Shaped Cloud: British Scientists' Opposition to Nuclear Weapons Policy, 1945–57', *Annals of Science*, 43:1 (1986), p. 3; David Holloway, *Stalin and the Bomb: The Soviet Union and Atomic Energy, 1939–1956* (London: Yale University Press, 1996), pp. 299–303.

78 NARA, RG 218, Central Decimal File 1948–50, Box 206, 'Brief of the Noyes Report on Radiological Weapons', Memorandum to Major General Alfred M Gruenther, 7 January 1951.

79 For examples, see: TNA, DEFE 5/10, 'Discussion of Bacterial Warfare by Atomic Energy Commission', Secretary of the Chiefs of Staff Committee, 3 February 1948, Annex II; TNA, DEFE 5/12, 'Atomic Energy – Strategic Requirements', Atomic Energy Sub-Committee, 14 August 1948. Also see its omission in: TNA CAB 158/3, 'Soviet Interests, Intentions and Capabilities', Secretary of the Chiefs of Staff Committee, 26 January 1948, Attached report.

80 The United Nations, Resolutions adopted by the Commission at its 13th meeting, Commission for Conventional Armaments, 12 August 1948. For a summary of disarmament efforts in the RW field, see: FCO 66/1135, 'Radiological Weapons Convention', Arms Control and Disarmament Department, 20 April 1978.

81 TNA, AB 15/769, 'Preliminary Note on Military Uses of Radioactive Materials Derived from Nuclear Reactors', W. G. Marley, 14 February 1949. Marley's involvement was in line with wider military interest: TNA, AB 16/4594, G. Hinds to M. Perrin, 10 March 1949.

meticulous assessor of scientific work and a cautious administrator.⁸² Marley had worked briefly on the atom bomb project at Los Alamos and was heavily involved in detecting the first Soviet atom bomb test in 1949.⁸³ Similar to Klaus Fuchs and Peierls, witnessing the explosion of the atomic bomb at Los Alamos had a significant impact. This also coincided with his prior experience of working on conventional explosives during the war, which led to him revealing in a public lecture that ‘I sometimes nowadays shudder at the things we did’.⁸⁴ In the post-war period, Marley devoted much of his time to defences against radiation and fallout. He urged officials to consider the impact of radiation and fallout from an atomic war. Focusing on defences against radioactivity, after being ‘more or less steered [there] by Cockcroft’, as a specialist on fallout and radiations he also considered RW.⁸⁵ His thorough report on the military uses of radioactive material, finished in February 1949, would act as the bedrock for British Cold War RW policy.⁸⁶

In his report, Marley warned that the radiations from fission products were potentially lethal and that there remained ‘no effective remedy’ once an individual was exposed.⁸⁷ He also re-iterated the three potential roles for radiological weapons: to contaminate the ground, be spread as a gas or dust, for poisoning the drinking water of a civilian population. But Marley went into far greater detail than earlier assessments, investigating how radioactive fission-products could be used, in what quantity they would be needed, and how they could be dispersed effectively against a target. In terms of the most controversial aspect, the poisoning civilian water supplies, radioisotope strontium-89 could be used to cause fatalities in a short space of time, with only a relatively small amount needed. An individual, with average drinking habits, would consume enough strontium-89 for it to reach fatal levels after just 2 days. Investigating an even more morally dubious option, Marley revealed that strontium-90 could also contaminate drinking water.⁸⁸ With a half-life of around 29 years, strontium-90 would cause gradual radioactive poisoning over an extended period. Casualties and health issues resulting from this form of poisoning would be harrowing, and span decades.⁸⁹

82 Norman Spoor, ‘Dr W. G. Marley’, *The Annals of Occupational Hygiene*, 1981, 24:2, 258–259; Margaret Gowing, *Independence and Deterrence: Britain and Atomic Energy 1945–1952*, Volume I: Policy Making (London: MacMillan, 1974), 162–165.

83 British Imperial War Museum, London, Photographic Archive, Marley W G (Dr), 2015–06–08, ‘Dr Marley’s Lecture’, 8 May 1973, p. 1; Michael Goodman, *Spying on the Atomic Bear: Anglo-American Intelligence and the Soviet Bomb* (Stanford, CA: Stanford University Press, 2007) 47, 95.

84 For Fuchs and Peierls see: Laucht, *Elemental Germans*, 125–126. For Marley, see: British Imperial War Museum, London, Photographic Archive, Marley W G (Dr), 2015–06–08, ‘Dr Marley’s Lecture’, 8 May 1973, pp. 1–2, 7, 17.

85 *Ibid.*, 17.

86 For his final report, see: TNA, AB 15/769, ‘Preliminary Note on Military Uses of Radioactive Materials derived from Nuclear Reactors’.

87 TNA, AB 15/769, ‘Preliminary Note on Military Uses of Radioactive Materials derived from Nuclear Reactors’.

88 TNA, AB 15/769, ‘Preliminary Note on Military Uses of Radioactive Materials derived from Nuclear Reactors’.

89 W. O. Caster, ‘From Bomb to Man’, Chapter 3 in *Survival: A Study of Superbombs Strontium 90 and Fallout*, ed. JM Fowler (London: MacGibbon & Kee, 1960), pp. 40–45.

Importantly for the future of British RW research, Marley significantly expanded upon existing scientific scepticism as to the severe limitations of radiological weapons. A ground attack could be mitigated by heavy rainfall or even the use of a water hose; both would dissipate the fission products and reduce the weapon's effectiveness. If fission products were formed into a gas or dust, this could be countered by an adapted respirator. Contaminating water supplies was difficult, as some of the fission products could be absorbed by mud in a reservoir or, if detected, filtered out. Marley also recognized the significant hardship involved in delivering radiological weapons. To protect workers, soldiers and scientists, a gamma-emitting radioisotope would require 'elaborate' shielding at all stages: in preparation, storage, and delivery.⁹⁰ If delivered by air, pilots would require around 4 inches of lead to block harmful radiations, but this heavy shielding would severely limit how much the aircraft could carry and for how long the pilot could fly.⁹¹ Furthermore, storage of fissionable material for radiological weapons would create a target for enemy bombers, which, if hit, would likely expose the domestic population to harmful radiations.

The other substantial problem investigated by Marley was the issue of half-life. The half-life of a particular radioactive substance measures the rate at which the radioisotope decays, but this can vary immensely depending on the radioisotope.⁹² Possible options for radiological weapons included yttrium-90, which has a half-life of under 3 days, and columbium-95 (now known as niobium-95), which has a half-life of around 35 days.⁹³ If the half-life is short, as with yttrium-90 or columbium-95, then the 'technical difficulties would be enormous'.⁹⁴ The fissionable material would emit dangerous levels of radiation, making it extremely hard to protect those assembling and delivering the weapon. A weapon with a short-half life could also not be stored for later use, as it would decay quickly. The worst facet of potentially using a radiological weapon with a short half-life was, however, not even a technical one, but a political and moral one. As Marley cautioned that

In attempting to cause early casualties by deposition of large amounts of [radioactive] material in the body, many of the survivors would no doubt die at periods ranging over a number of years from osteogenic sarcoma in the skeleton: this would probably prove to be a serious political embarrassment.⁹⁵

Osteogenic sarcoma is the development of cancer in the bone, which can become widespread if an individual is exposed to large doses of radiation.⁹⁶ Long-term health issues

90 TNA, AB 15/769, 'Preliminary Note on Military Uses of Radioactive Materials derived from Nuclear Reactors'.

91 TNA, AB 15/769, 'Preliminary Note on Military Uses of Radioactive Materials derived from Nuclear Reactors'.

92 Rotblat, *Nuclear Radiation in Warfare*, p. XV.

93 Charles Ferguson and Michelle Smith, 'Assessing Radiological Weapons: Attack Methods and Estimated Effects', *Defence Against Terrorism Review*, 2:2 (2009), p. 20.

94 TNA, AB 15/769, 'Preliminary Note on Military Uses of Radioactive Materials derived from Nuclear Reactors'.

95 TNA, AB 15/769, 'Preliminary Note on Military Uses of Radioactive Materials derived from Nuclear Reactors'.

96 A. Berrington de Gonzalez, A. Kutsenko and P. Rajaraman, 'Sarcoma Risk after Radiation Exposure', *Clinical Sarcoma Research*, 2:18 (2012), p. 1.

arising from radiation exposure would create disturbing accounts of civilian deaths, spread over many years after the weapon's actual use, and undoubtedly have led to sustained and severe political fallout. From a moral standpoint, the poisoning of an enemy's civilian population would have crossed a line and drawn severe criticism, domestically and internationally.⁹⁷ Even though civilians could, in theory, evacuate a target area, they could still have been exposed to significant levels of radiation. Although they may not die, they would live with the medical consequences for the rest of their lives. The flip side, of using fissionable material with a longer half-life, would also have raised serious moral questions, as well as technical and political problems. Civilians would have more time to escape the contaminated area, but they would still be exposed to radioactive materials, and, with a longer half-life, they would be forced from their homes for a longer period. For defence planners, this was also a disadvantage, as an area contaminated for longer than necessary would hinder the movement of forces and limit the possibility of a counter-attack.⁹⁸ In addition, longer half-life fission products were militarily less effective, as troops would be able to traverse the contaminated terrain quickly without it proving fatal.

In concluding his detailed and secret assessment, Marley was clearly concerned by the prospects of RW. He emphasized the political, military and moral costs of radiological weapons, and he urged for further research into defensive measures to protect soldiers and civilians, the effects of radioactive contamination and the impact of fallout from an atomic bomb.⁹⁹

In 1943, officials in Tube Alloys had viewed RW as a more humane weapon of war, but after the dropping of the atomic bombs on Japan and as further information came to light on the effects of radiation on the human body, this view was increasingly untenable. Marley's intervention importantly shows attitudes towards the plausibility and viability of RW hardening. In line with earlier scepticism expressed by the MAUD Committee and Chadwick, Marley's findings seemingly laid a significant confirmatory marker in the history of the British engagement with controversial radiological weapons. His decision to query the rationale for developing a radiological weapon had a profound and lasting impact on how senior British officials viewed the RW field.

Based on Marley's research, the Director of the Atomic Energy Research Establishment at Harwell, John Cockcroft, determined that radioactive dust was 'about as effective as mustard gas'.¹⁰⁰ Cockcroft himself had long taken a strong interest in the effects of

97 Marley devoted much of his later career towards seeking countermeasures and defences against radiation exposure, until he retired in 1973: British Imperial War Museum, London, Photographic Archive, Marley W G (Dr), 2015-06-08, 'Dr Marley's Lecture', 8 May 1973.

98 TNA, AB 15/769, 'Preliminary Note on Military Uses of Radioactive Materials derived from Nuclear Reactors'.

99 TNA, AB 15/769, 'Preliminary Note on Military Uses of Radioactive Materials derived from Nuclear Reactors'.

100 TNA, WO 188/2192, 'Radiological Weapons', Minutes of Meeting held by PDSR(D), 21 January 1949. Although this statement is dated just before Marley's final report, Cockcroft likely drew heavily from Marley's analysis. It is likely Cockcroft saw an earlier version, given that he was the Director of Harwell and Marley worked under him.

radiation. He was present from the beginning after discussing the issue with the Defence Services Panel in 1941 and was responsible for pushing Marley towards the effects of radiation. On becoming Director of Harwell, it was he who arranged for the Medical Research Council to install a unit working on the biological aspects of radiation, which was adjacent to the Harwell establishment.¹⁰¹ Alongside colleagues from the MRC, he was also a member of committees on the Medical and Biological Applications of Nuclear Physics, the Tolerances Doses Panel and the Protection Sub-Committee.¹⁰² Marley also often attended the meetings of these committees.¹⁰³

Cockcroft's comparison, while revealing his serious doubts over military potential, further highlighted the questionable nature of resorting to radiological weapons. He simultaneously questioned their perceived military value, by comparing them to a more easily prepared, deployed and stockpiled chemical warfare (CW) agent, and placed them morally on a par with controversial chemical weapons. After the nerve agent discovery, mustard gas was also at the lower end of British CW capabilities.¹⁰⁴ Following Marley's and Cockcroft's sceptical assessments, the costs and difficulties of radiological of weapons were thought too substantial to warrant a significant British effort in 1949.¹⁰⁵

Although secret research findings were sceptical, in August 1950, Professor Edward Shire, a nuclear physicist based at the University of Cambridge, publicly warned of the dangers of 'radioactive dusts', calling for the government to expand its civil defence efforts.¹⁰⁶ Unbeknownst to Shire, behind closed doors, this was already occurring. Coinciding with Marley's concerns, officials at Harwell, the Home Office and the Medical Research Council were already investigating.¹⁰⁷ Research into defence against radiological weapons, especially harmful radiations, was greatly assisted by becoming enmeshed with defence against radioactive fallout. Both areas, centering on the development of defences against radiation, overlapped significantly. Assessing and improving civil defence preparedness against gamma radiation and radioactive contaminated rain-water, resulting from an atomic explosion, were deemed of 'vital importance' by the DRPC.¹⁰⁸ Other high priorities included studies into the dangers of inhaled and ingested radioactive material, and research into the maximum permissible levels of radiation in the human body. These avenues of research on the effects of radiation on humans thus held dual value, informing defences against nuclear fallout and facilitating a better understanding of the RW field.

101 Mark L. E. Oliphant and Lord Penney, 'John Douglas Cockcroft, 1897–1967', *Biographical Memoirs of Fellows of the Royal Society*, 14 (1968), p. 173.

102 Oliphant and Penney, 'John Douglas Cockcroft, 1897–1967', pp. 173–4.

103 Oliphant and Penney, 'John Douglas Cockcroft, 1897–1967', pp. 173–4.

104 William King, 'The British Nerve Agent Debate: Acquisition, Deterrence and Disarmament, 1945–1976' (PhD Dissertation, The London School of Economics and Political Science, 2019), pp. 64–70.

105 Marley's findings also shaped Commonwealth views, see: TNA, AB 16/327, M. W. Perrin to W. G. Penney, 15 July 1949.

106 *The Times*, 'Radio-Active Dust Poison', 9 August 1950, p. 4.

107 TNA, DEFE 10/27, 'Civil Defence Research Requirements', Defence Research Policy Committee, 23 May 1950, Attached letter, Enclosed list.

108 TNA, DEFE 10/27, 'Civil Defence Research Requirements'.

Despite keen interest in the effects of radiation, scepticism over the possibilities of RW was increasingly taking root in government circles. In May 1951, the Home Office reviewed possible future developments in atomic weapons.¹⁰⁹ Home Office officials noted, along Marley's line, that it could take the form of radioactive materials dropped over a wide area by aircraft, with the intention of contaminating persons, areas, or equipment with radioactivity.¹¹⁰ Building on early analysis conducted at Porton Down and by nuclear scientists such as Marley, Home Offices officials noted that the disadvantages associated with RW might well cause an enemy to conclude that the effort involved was not 'worth while'.¹¹¹ Delivery of radioactive material would require a considerable airlift, and that 'it seems likely that chemical agents would be better than radioactive ones for neutralizing an area'.¹¹²

In December 1951, benefitting from increasing scientific focus on the effects of radiation, Marley produced an updated assessment of radiological weapons.¹¹³ Marley's views on RW had hardened. In this highly critical report, he focused on the most promising yet controversial aspect of radiological weapons, the contaminating of food and water supplies. And, in setting about dismissing the entire field, Marley, like Cockcroft before him, compared one terrible form of warfare to another.

Marley concluded that radiological weapons did not have a viable military role in British defence policy, and that they fell short when compared to chemical weapons.¹¹⁴ Both RW and CW could be used to deny territory to an enemy, force the evacuation of a target area, and strike fear into the opposing side. However, from a purely tactical standpoint, the military benefits and ease of use of chemical weapons far outweighed radiological weapons. Advances in the CW field had simplified the means of delivery. Spray tanks, artillery shells, cluster bombs, and land-mines facilitated the use of chemical weapons, all while the operator was relatively safe in protective gear.¹¹⁵ Delivering radiological weapons, on the other hand, posed 'enormous' technical difficulties.¹¹⁶ Radioisotopes that only emitted beta radiations, such as strontium-89, were judged to

109 TNA, HO 228/14, 'Possible Trend of Future Developments in Atomic Weapons', Summary of papers read at the meeting held between the Staff of the Civil Defence Staff College, the Civil Defence Schools and the Scientific Adviser's Branch, 16-17 May 1951.

110 *Ibid.*

111 For an insight into Porton Down's engagement with RW, see: TNA, AB 6/544, 'Defence: military liaison with Porton: fission product warfare', 1948-1951; TNA, WO 188/2256, 'Liaison with Atomic Energy Research Establishment (AERE) Harwell', 1951-1969.

112 TNA, HO 228/14, 'Possible trend of future Developments in Atomic Weapons', Summary of papers read at the meeting held between the Staff of the Civil Defence Staff College, the Civil Defence Schools and the Scientific Adviser's Branch, 16-17 May 1951.

113 TNA, AB 15/1773, 'Radioactivity Hazards to Food Supplies in Atomic Warfare', W. G. Marley, 3 Dec. 1951.

114 *Ibid.*

115 For an example of nerve agent delivery methods, see: TNA, DEFE 10/30, 'Development of Anti-Tank Weapons in the Long Term', Sub-Committee on Anti-Tank Defence Measures, 22 Oct. 1951.

116 TNA, AB 15/1773, 'Radioactivity Hazards to Food Supplies in Atomic Warfare', W. G. Marley, 3 December 1951.

compare 'very unfavourably with CW agents'.¹¹⁷ Marley's reproach, as one of Britain's principal RW experts, was damning, and he roundly dismissed radiological weapons.¹¹⁸ His reports played a central part in senior British defence officials accepting that RW was not an improvement on, or a viable alternative to, CW. After reviewing his findings, the DRPC and the CoS accepted that radiological weapons were not viable for the Cold War.¹¹⁹

Dismissal and death-dust

Although Marley's assessments and Cockcroft's dismissal all but confirmed British discussions and interest in radiological weapons, for some defence officials, hope still lingered. In 1952, spurred on by United States RW research, the British War Office and Air Ministry wished to re-evaluate the military applications of 'radioactive dust'.¹²⁰ Following consultations with Marley, though, defence officials again accepted that radiological weapons were too costly and not on a par with chemical weapons.¹²¹ This rejection of RW was compounded when, in October 1953, the infeasibility of the entire venture was fully appreciated. Based on existing levels of production at the Windscale Piles, built to provide atomic material for the development of British nuclear weapons, the output of radioactive material would 'never be sufficient to contaminate more than a very small area'.¹²² The level of effort required to overcome this severe supply issue was unacceptable, as it would require significant funding and detract from the development of nuclear weapons.¹²³

Besides the recognition of chronic supply issues and political costs, the question of a British RW capability was also significantly influenced by developments in nuclear weapons, and the priority attached to the field. This priority compounded supply issues, but also undermined interest in the RW field through a far superior means of utilizing atomic energy for military purposes. A key marker had been the 1952 Defence Policy and Global Strategy Paper (GSP), which confirmed the centrality and importance of nuclear weapons to British defence policy.¹²⁴ Shortly after, in October 1952, Britain tested its first atomic bomb.¹²⁵ Following these developments, with it coinciding with the advent

117 TNA, AB 15/1773, 'Radioactivity Hazards to Food Supplies in Atomic Warfare'.

118 TNA, AB 15/1773, 'Radioactivity Hazards to Food Supplies in Atomic Warfare'.

119 TNA, DEFE 5/31, 'Report on the Military Aspects of Atomic energy', Deputy Chairman of the Defence Research Policy Committee, 6 June 1951, attached report; TNA, DEFE 4/44, Minutes of Meeting, Chiefs of Staff Committee, 20 June 1951.

120 TNA, AB 16/1129, E. Davis to V. Wainright, 11 December 1952.

121 TNA, AB 16/1129, E. Davis to V. Wainright, 11 December 1952; TNA, AB 16/1129, W. Scott to E. Davis, 6 February 1953.

122 TNA, DEFE 32/3, 'Radiological Warfare', Chairman of the OAW Working Party, 26 October 1953; Douglas Holdstock, 'Health Effects at Home', Chap. 10 in *The British Nuclear Weapons Programme 1952-2002*, ed. F. Barnaby and D. Holdstock (London: Frank Cass, 2003), p. 115.

123 TNA, DEFE 32/3, 'Radiological Warfare', Chairman of the OAW Working Party.

124 Jones, *UK Strategic Nuclear Deterrent, Volume I*, p. 21.

125 Jones, *UK Strategic Nuclear Deterrent, Volume I*, pp. 25-6.

of the thermonuclear age, greater funding, support and expertise would need to be devoted to nuclear weapons research and development. The substantial shadow cast by the dominance of nuclear weapons was also not a phenomenon unique to the RW field, but an experience shared by other WMDs such as chemical and biological weapons at this time.¹²⁶

In November 1953, the CoS removed any possibility of Britain acquiring radiological weapons.¹²⁷ Radiological weapons were judged a poor substitute for chemical weapons, economically and in terms of scale of use, and acquiring them was thought to impede upon other more important projects, and especially the development of atomic weapons. The CoS thus accepted that 'no effort should be devoted in this country to the development of weapons of radiological warfare'.¹²⁸ In addition to moral concerns and the existing scepticism as to the practical difficulties of RW, the primacy of nuclear deterrence, in an economic climate requiring cutbacks to defence expenditure, was damning.

While military interest in the application of radioactive material as a weapon waned, the use of radioisotopes in other areas of controversial defence research was increasing. From the early 1950s, Porton Down became more involved with radioactive materials.¹²⁹ At Porton, further trials investigating defensive measures against harmful radiations from a nuclear explosion were conducted, and scientists used radioactive products to understand the effects of chemical and biological weapons.¹³⁰ Numerous experiments on animals, including rats, cats, and dogs, used radioactive nerve agents. In these experiments, sarin or VX was labelled with phosphorus-32 for the monitoring of how nerve agents spread throughout the body.¹³¹ Alternative controversial uses of radioactive material in defence science were thus still occurring, just no longer in relation to offensive RW.

The categorical dismissal of radiological weapons by the CoS and British experts was somewhat mitigated through trilateral cooperation with the United States and Canada. Yearly trilateral meetings, which were primarily intended to foster and deepen cooperation in the closely integrated and coordinated CBW fields, had expanded from the early 1950s to include defences against radiation and RW.¹³² This facilitated the division of effort and the sharing of research findings between the three countries. Similarly, there were also tripartite conferences on radiation tolerance doses, which both Marley and

126 Brian Balmer, *Britain and Biological Warfare: Expert Advice and Science Policy, 1930–65* (Hampshire: Palgrave, 2001), pp. 154–5; King, 'The British Nerve Agent Debate', pp. 83–5.

127 TNA, DEFE 4/66, Minutes of Meeting, Chiefs of Staff Committee, 5 November 1953.

128 TNA, DEFE 32/3, 'Radiological Warfare', Chairman of the OAW Working Party, 26 October 1953; TNA, DEFE 4/66, Minutes of Meeting, Chiefs of Staff Committee, 5 November 1953.

129 Martino-Taylor, *Behind the Fog*, p. 67.

130 Martino-Taylor, *Behind the Fog*. For publicity surrounding the use of radioactive material in BW trials, see: J. Walker, 'Germ War Tests: Official', *Daily Mail*, 12 March 1954, p. 1.

131 For example, see: TNA, WO 195/12704, 'Preliminary Studies on the Distribution and Fate of P32 in Preparations Poisoned with Radioactive GB', K. M. Wilson, 26 January 1954.

132 Gradon Carter and Graham S. Pearson, 'North Atlantic Chemical and Biological Research Collaboration: 1916–1995', *Journal of Strategic Studies*, 19:1 (1996), pp. 85–7; TNA, WO 188/2651, W. Cawood to D.W.R., 23 August 1955.

Cockcroft attended.¹³³ Cooperation was close, but RW research which overlapped significantly with nuclear weapons research was not shared. Some joint assessments by RAND on using tantalum-based weapons, for example, were withheld, even though British officials were already aware of this research through other means.¹³⁴ Despite these occasional limitations, from the early 1950s close trilateral cooperation proved a crucial avenue through which Britain, with its increasing emphasis on defensive measures against radiation, was able to maintain access. Crucially, this included access to the much more extensive RW effort of the United States.¹³⁵

In 1955, information from the more advanced United States RW programme surprisingly reinforced the British decision to dismiss radiological weapons. After millions of dollars and years of intensive research, British experts observed that the United States was still not ready to use radiological weapons at the outbreak of war.¹³⁶ This was in spite of the United States Chemical Corps planning to test a Tantalum-182 bomb weighing 2,500 lbs, and having designed a large cluster bomb for widespread ground contamination by the end of 1953.¹³⁷ One cluster bomb could have covered an area the size of Gibraltar, twice over, with radioactive material. In order to avoid considerable civilian casualties, and reflecting the extremely controversial nature of radiological weapons, United States authorities also planned to drop leaflets over the target area, instructing civilians to evacuate.¹³⁸ In April 1955, with Cockcroft's guidance the DRPC, even after recognizing these significant advances, reaffirmed its negative assessment of radiological weapons and the 1953 CoS decision, maintaining that radiological weapons were not a viable avenue for development or a serious threat.¹³⁹

This British dismissal of radiological weapons was now widely supported by defence officials, confident in scientific assessments as to the disadvantages of RW use and despite the perceived Soviet threat. Slightly more alarmist reports by the Joint Intelligence

133 British Imperial War Museum, London, Photographic Archive, Marley W G (Dr), 2015–06–08, 'Dr Marley's Lecture', 8 May 1973, p. 14.

134 TNA, DEFE 10/806, 'Radiological Warfare', Joint Secretaries of the Atomic Energy Sub-Committee, 17 February 1955, Annex; TNA, DEFE 10/806, Minutes of Meeting, Atomic Energy Sub-Committee, 13 April 1955.

135 TNA, WO 188/2347; TNA WO 188/2345. Also see: University of East Anglia, Zuckerman Archive, SZ/MOS(3)/1, Minutes of Meeting, Advisory Council on Scientific Research and Technical Development, 29 November 1956; TNA, DEFE 7/763, 'Tripartite Conference on Nuclear Weapons Effect, 1957', Secretary of the Defence Research Policy Committee, 13 March 1957.

136 TNA, DEFE 10/806, Minutes of Meetings, Defence Research Policy Sub-Committee, 13 April 1955.

137 NARA, College Park, RG 330, Entry 341, Box 351, 'Irradiation of Tantalum', Memorandum for Chairman MLC, 3 April 1951; TNA, DEFE 32/3, 'Radiological Warfare', Note by the Chairman of the OAW Working Party, 26 October 1953.

138 NARA, College Park, RG 330, Entry 341, Box 351, 'Irradiation of Tantalum', Memorandum for Chairman MLC, 3 April 1951; TNA, DEFE 32/3, 'Radiological Warfare', Note by the Chairman of the OAW Working Party, 26 October 1953.

139 TNA, DEFE 10/806, Minutes of Meetings, Defence Research Policy Sub-Committee, 13 April 1955.

Committee warned that Soviet manuals devoted ‘considerable attention’ to defences against radioactive contamination and its deliberate dissemination.¹⁴⁰ But, in a worst-case scenario and in line with Marley’s findings, defence planners observed that radiological weapons would be easily detected and mitigated with defensive measures.¹⁴¹ In addition to the economic, political, and military issues with radiological weapons, and the dominance of nuclear weapons, there was thus also a lack of a significant perceived external threat to spur on the acquisition of a retaliatory capability or deterrent.

Coinciding with this British dismissal of offensive RW was a remarkable tide of publicity that swept in from the mid-1950s, revealing the hostile public and international climate in relation to radioactive fallout and harmful radiations. In a substantial break from prior stringent levels of secrecy, this greater flow of information was primarily fuelled by fears of fallout from nuclear weapons tests. Although there was only a small chance of damage to human health on the individual level, fallout became an extremely controversial area for politicians and scientists.¹⁴² Public interest dramatically spiked in November 1955, with the Soviet testing of a hydrogen bomb.¹⁴³ Greater public awareness would play a substantial part in the late 1950s when public fears intensified with stories of leukaemia, the Windscale disaster, and the poisoning of milk from radioactive fallout.¹⁴⁴ One notable radioisotope, which would worry the public and cause serious difficulties for British politicians throughout this later period, was strontium-90.¹⁴⁵ The year 1955 represented a crucial confirmatory year; public awareness of, and anxiety over, the effects of harmful radiations significantly grew, and a weapon for war was resoundingly and conclusively dismissed.

A weapon too far

From 1940, British scientists and defence officials explored the military potential of controversial radiological weapons. Early ventures, including by Alan Nunn May and

140 TNA, CAB 158/20, ‘Russian Research and Development’, Joint Intelligence Committee, 26 April 1955, Annex B.

141 For this line of thinking, see: TNA, AB 16/1129, W. A. Scott to E. D. Davis, 6 February 1953.

142 Toshihiro Higuchi, ‘Radioactive Fallout, the Politics of Risk, and the Making of a Global Environmental Crisis, 1954-1963’ (PhD Dissertation, Georgetown University, Washington, DC, 2011), pp. 3-4. See some of the government response and management of this in: TNA, PREM 11/2175; TNA, PREM 11/2553; TNA, DEFE 16/199; TNA, BD 25/99.

143 Holloway, *Stalin and the Bomb*, pp. 2, 295-318.

144 For further details, see: Robert A. Divine, *Blowing on the Wind: The Nuclear Test Ban Debate, 1954-1960* (Oxford: Oxford University Press, 1978), pp. 84-314; Joan Smith, *Clouds of Deceit: The Deadly Legacy of Britain’s Bomb Tests* (London: Faber and Faber, 1985), pp. 89-101; Fred Roberts, *60 Years of Nuclear History: Britain’s Hidden Agenda* (Charlbury, Oxfordshire: Jon Carpenter, 1999), pp. 63-5; Jodi Burkett, ‘The Campaign for Nuclear Disarmament and Changing Attitudes towards the Earth in the Nuclear Age’, *The British Journal for the History of Science*, 45:4 (2012), p. 630.

145 See political concerns and publicity of strontium-90 in: TNA, PREM 11/2553; TNA, BD 25/99.

scientists working on Tube Alloys, revealed a promising alternative use of radioactive material, which could possibly render areas inhospitable without causing immediate fatalities. This initial optimism, however, soon soured. And, with greater appreciation of the significant difficulties involved radiological weapons faced increasing scrutiny. Technical difficulties, as well as advances in chemical and nuclear weapons, supply shortages, and political concerns, squeezed any aspirations defence officials had for a British capability. Given these constraints, which combined with their own aversion and concerns, radiological weapons were conclusively dismissed by British scientists in the post-war period. The RW field was not completely abandoned, though, as in searching for defences against radiation, Britain remained active, and it was to this endeavour which Marley dedicated the rest of his working life.¹⁴⁶

Assessing the British RW experience sheds much needed light on secret British activities and research. It fills an important gap in our understanding of nuclear history and adds to our appreciation of the drivers, limitations and constraints involved in this troubling form of warfare. The poisoning of wells, the slow build-up of strontium-90 in the body to fatal levels and substantial cluster bombs for mass-dispersal all emphasise the especially dubious nature of this avenue of weapons development. Nevertheless, even though British scientists received ethically questionable research findings and investigated the potentials of poisoning thousands of civilians with radioactive material, this largely remained a path not taken. Weapons were not developed or mass-produced by Britain, and a potentially far more gloomy and abhorrent experience was avoided.

One of the most important reasons why Britain never ventured as far as the United States down this controversial path was the divergent opinions of key scientists. The United States crucially had strong support from influential figures such as Arthur Compton, J. Robert Oppenheimer and Stafford Warren, as well as greater funding and a larger supply of radioactive material. In stark contrast, British scientists, including Chadwick, Marley and Cockcroft, dismissed the potentials of radiological weapons. By taking this highly sceptical stance, they effectively set the tone and path of British engagement with the RW field. Defence officials, reliant on their assessments, could do little to overturn this scientific condemnation.

The findings of this article also contribute and, to a degree, reinforce Edgerton's critique of the traditional image of the conservatism of soldiers and the creativity of civilians in the history of science and technology.¹⁴⁷ What we see here is more a conservatism, and certainly strong scepticism, of scientists and formerly civilian scientists in a field of initially promising weapons development. Defence officials, such as with the CoS, were inquiring as to the feasibility of new advances, and scientists returned with a negative verdict. While their findings that it would have proven less effective and more costly than other means of warfare supported the dismissal of RW, it was prominent British scientists who were instrumental in closing this avenue of potential weapons

146 See: British Imperial War Museum, London, Photographic Archive, Marley W G (Dr), 2015-06-08, 'Dr Marley's Lecture', 8 May 1973.

147 David Edgerton, *Warfare State: Britain, 1920–1970* (Cambridge: Cambridge University Press, 2006), pp. 309, 326–30.

development. Scientists, to an extent, were sceptical and conservative, and defence officials were pushing for investigating the viability of new advances.

Ultimately, during the Second World War and early Cold War, arguments in favour of the use and acquisition of radiological weapons were grossly outweighed by the negatives. Radiological weapons were judged not to provide enough benefits, deemed far too costly and technically difficult, and they never realistically challenged the pre-eminence of chemical and nuclear weapons in British defence planning. Rather than settling for the simple dispersal of radioactive material, the nuclear bomb was found a far more cost-effective and viable means of war, as indeed were chemical weapons. Politically, technically, economically, morally and militarily, radiological weapons were found wanting, and for Britain, they proved a weapon too far.

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