THE PROTECTION AND COMPENSATION OF WORKERS EMPLOYED IN THE URANIUM MINING INDUSTRY IN AUSTRALIA

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> No man has a right to any good without partaking of the evil by which that good is necessarily produced; no man has a right to security by another's danger; nor to plenty by another's labour; but as he gives something of his own which he who meets the danger or undergoes the labour considers as equivalent.
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> Samuel Johnson

Introduction

Uranium mining has been taking place in Australia, with numerous disruptions, since shortly after the turn of the century. Despite the qualified opposition to the mining of this commodity expressed in the political platform of the present federal government, it is safe to assume that, while there remains an international market for uranium, the mining of it in Australia will continue, if only in projects already embarked on and perhaps with interruptions, until virtually the end of the century.

Like all industrial activity, uranium mining involves hazards to the health and safety of persons directly engaged in it. One of the purposes of this paper is to outline those hazards peculiar to uranium mining because of the radioactive nature of uranium ore, insofar as they have been disclosed in technical publications. There will then be a treatment of the question, to what extent has the law provided for the protection of uranium-mine or -mill workers from avoidable injury peculiar to the commodity. It will be seen that the law's preventative structures were completely inadequate to the task of safeguarding persons engaged in uranium mines and mills until the end of the last decade; indeed, given that substantial and reliable information as to the dangers of radioactive substances was disseminated internationally as long ago as 1920, one could

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fairly describe the approach of governments, prior to 1975, to the protection of uranium-mine and -mill workers from radiation hazards as cavalier. Fortunately, properly structured controls are now being imposed.

Even the best safety and accident-prevention programmes are liable to fail, whether in consequence of human error or because the unforeseeable eventuality is realised in fact. Despite the preventative structures at present being erected, and despite that no injuries attributed to radiation exposure in an uranium mine in Australia have been documented as yet,[1] it is inevitable (given the incidence of lung cancers among North America uranium-mine workers) that at least a small proportion of persons engaged in the uranium-mining industry in Australia will complain of diseases attributable to their employment. This paper will deal (with admitted superficiality) with the question, to what extent will the law's existing compensatory mechanisms (common law and statutory) provide for the just and equitable compensation of uranium-mine and -mill workers who sustain diseases peculiar to their employment, diseases which are quite dissimilar in manifestation and effect from the immediate, traumatic, evident industrial injury through accident with which the law has struggled to come to grips since the advent of the industrial revolution. One of the diseases commonly (although not, of course, solely) attributed to uranium mining is lung cancer. Lung cancer has been empirically associated with uranium mining since 1913, although diseases of the respiratory tract were known among workers in mines where pitchblende was disturbed as long ago as the 15th century.[2] More recently, claims have been made that disease other than cancer can be expected to result from sustained exposure even to low levels of ionising radiation. The capacity of the law to deal with cancers and other diseases of long latency periods is assessed at the end of the paper.

There are two reasons why legal policy-makers should act with special caution in this particular context, in the interests not only of the workers involved but also of the wider community. First, in the present recession, accompanied as it is by a high level of unemployment, the job choices available to skilled and unskilled mining workers are diminishing. In an absolute sense, they do not have the freedom either to abstain from employment in the industry or, through their industrial organisations, to dictate that their participation in the workplace shall be as free of hazard

1. An Award of $52,000 was paid to a worker at the Lucas Heights facility whose leg was amputated in consequence of radiation burns in 1958: see *Atomic Industrial Forum*, April, 1958 at 27. In 1979, the Health Commission of South Australia began an investigation of claims that former workers at the Radium Hill mine were presenting with an increased incidence of cancer. The investigation has proved inconclusive.
2. R.M Fry *Radiation Hazards in Uranium Mining and Milling* (1975) 18; *Atomic Energy in Australia* (No.4) 2; British Columbia *Report of the Royal Commission of Inquiry into Uranium Mining* (1980) Vol I 59-60 (hereafter, the "B.C. Royal Commission Report")

as science and technology permit. That being the case, it behoves society as a whole, which expects to benefit financially through uranium mining, to accept responsibility to ensure that hazards in this particular workplace are contained as far as is reasonably practicable. In addition, the work force should be permitted, through its appointed representatives, to participate in the enforcement and supervision of such legal safety standards as apply in the workplace. Given that the impact of ionising radiation on the human body is not detectable by the human senses, so that the worker is personally unaware of exposures which he is undergoing and can do nothing to mitigate their effects, it is imperative that the law require a complete and comprehensive program of education as to the risks inherent in this particular mode of employment, as to the means available to minimise those risks and as to the financial and health consequences of the materialisation of those risks (that is, the extent to which injuries are certain to be adequately compensated).[3] It remains to be seen whether controls presently being implemented in Australia satisfy these policy objectives.

Secondly, the evidence that exposure to radioactive substances, such as uranium, induces disease in human beings is indirect. There is clear proof that exposure to high levels of ionising radiation is harmful: witness the casualities of the Hiroshima and Nagasaki and Marshall Island bomb blasts. However, it is not absolutely clear that exposure to low levels of radiation is necessarily harmful; the evidence in this respect is largely statistical. Nor is it clear whether there is a threshold below which exposure will not be harmful. However, as will be seen, the law has fixed objective limits or standards of exposure for uranium-mine and -mill workers which necessarily assume that, if those limits are adhered to, injuries will not be numerically significant. This assumption is under challenge from within the medical profession and only time will tell whether it is right or wrong. Given the uncertainty of the information base, one could argue that ethics require that far more cautious standards be adopted than have in fact been promulgated; more to the point, unless the uncertainty is dispelled, claims justification of which must remain doubtful will be made that the protective mechanisms have failed and that a compensable injury has occurred.

Modification of the preventive mechanisms is very much in the hands of the medical profession and industrial organisations. The role of the legal technician in relation to accident prevention is to ensure that the protective structures are enforceable. On the other hand, modification of compensation schemes is controlled by the legal profession. Consistently

3. See the B.C. *Royal Commission Report*, Vol 1, 57-58 and J.A. Page and G.B. Sellers "Occupational Safety and Health" (1970) 59 *Kent L J.* 114, 140-144; Ontario *Report of The Royal Commission on Health and Safety of Workers in Mines* (1976) (the "Ham Report") 77-78, 250, 258.

with the past development of our systems of injury compensation, one can predict that the law's response to claims for compensation arising out of injuries attributed to uranium mining will be piecemeal, reluctant and conservative. Claims will be channelled through existing regimes. Change will be resisted until it is clear that these regimes are at breaking point. In Australia, given the relatively small numbers of persons engaged and likely to be engaged in uranium mining and milling, that breaking point may not be arrived at. If the numbers of persons affected were high enough, the strain on the existing systems of compensation would result largely from the fact that injuries are often inflicted by radiation reacting synergistically with some other agent and from the fact that a particular radiation injury does not identify its precipitating agent.[4] Unlike the traumatic, traceable, immediate and observable industrial injury with which our compensation schemes cope, the injuries induced by radiation will often be contingent, anonymous and deferred.[5] The paper will seek to show that the logical way to provide compensation for injuries of these kinds is by way of the creation of a compensation fund on which provisional, periodic and reviewable yet limited claims might be made within a lengthy limitation period, independently of proof of fault on the part of any person. Such a scheme of compensation is wholly incompatible with the approach of the common law to the compensation of accidental injuries. Furthermore, it is fair to say that such a fund would be difficult (in a political sense) to impose on the uranium-mining industry in Australia. Nevertheless, the merits and demerits of such a fund will be canvassed in the conclusion, along with a discussion of less thoroughgoing reforms.

History of Uranium Mining in Australia

Uranium bearing ores were first discovered in Australia near Carcoar in New South Wales, in 1894, in the form of torbernite. Subsequently, in 1904 uranium mineralisation in the form of euxenite was discovered near Marble Bar in Western Australia. Operations for the recovery of

4. Perhaps the most thorough general treatment of the capacity of the law to respond effectively to, and of the response which the law will make to, injuries attributable to radiation is E.B. Stason, S.D. Estep and W. J. Pierce, *Atoms and the Law*, (1959), Parts I and II. The number of persons engaged in completed uranium mine projects in Australia (as to which, see the text accompanying notes 8 and 9, infra) is dwarfed by the number of personnel engaged in the atomic weapons test program conducted around Maralinga in South Australia. Some 9,000 defence personnel are believed to have been involved in the tests. Litigation to recover damages for personal injuries allegedly due to radiation exposure during the tests has been instituted on behalf of a serviceman, in the Supreme Court of New South Wales, and on behalf of an aboriginal occupant of the bomb-site area, in the Supreme Court of South Australia.
5. See J-P. Pierard *Responsabilite Civile, Energie Atomique et Droit Compare* (1963) 473-474, 485.
6. South Australia, Dept. of Mines *Geological Survey of South Australia* Bulletin 43, 148 (hereinafter Bulletin 43). As far as less significant uranium mineralisation in South Australia is concerned, see S.A., Dept. of Mines *Geological Survey of South Australia* Bulletin 34, 44-90, and Bulletin 30, Part V.

radium from uranium ore in commercial quantities began at Radium Hill in South Australia, following a discovery in 1906, and at nearby Mt Painter in 1910.[6] Mining was carried on by the Radium Extraction Company of South Australia Ltd and by the Mt Painter Proprietary Company. Several shafts, to a maximum depth of 100 feet, were sunk. Mining halted in 1914 but was resumed in 1923 and continued until 1932.[7] The product of these mines was processed near Adelaide.

Commercial mining of uranium in Australia received its greatest impetus in 1944, when the federal government received a request from the British government to investigate uranium-bearing areas in Australia. At this stage, the governments both of the United Kingdom and of the United States of America were seeking uranium for military purposes. Exploratory work was recommenced at Radium Hill and at Mt Painter in 1944. The mine at Radium Hill was re-opened in 1948 under the direct supervision of the South Australian Department of Mines. The mine went into full-scale production in November, 1954, to close, virtually depleted, in 1961. At Radium Hill a shaft was sunk to a depth of 1,370 feet. Some 450-600 tons of uranium-bearing ore were removed daily, while production was at its peak. At this stage the workforce at the mine numbered approximately 400. A concentration plant was constructed at the site and the concentrate was transported to Port Pirie, where the uranium was extracted. In all, some 1 million pounds of U_3O_8 were removed from the mine and sold to the British government.[8] At present, uranium is not being mined in commercial quantities in South Australia.

It has been in the Northern Territory and Queensland that the most significant uranium-mining operations have been conducted. In Queensland, uranium-bearing ore in commercial quantities was first discovered in 1954 near Mt Isa, at a site which became known as Mary Kathleen. Open-cut mining to a depth of 61 metres began at this site in October, 1956 and continued on the part of Mary Kathleen Uranium Ltd until 1963, when demand fell. In this first phase of recovery, some 3,714 tons of $U_3 O_8$ were produced. The mine was recommissioned in 1975 and mining continued, resulting in the production of some 2,500 tons of $U_3 O_8$ before operations were formally concluded in October 1982. Ores recovered from the mine were processed in an on-site treatment plant completed in June, 1958. The average mining workforce at Mary Kathleen fluctuated between approximately 63 and 500.[9] Mining operations for the recovery of uranium at Ben Lomond, in Queensland, are still in the exploratory phase.

7. Bulletin 43, 148-149
8. Radium Hill, in Australian Atomic Energy Commission, *Uranium in Australia* (1962) 21
9. Mary Kathleen, in Australian Atomic Energy Commission supra n.8,at 41. The figure of 500 was furnished by letter by the Director-General of Mines (Qld).

In the Northern Territory are located Australia's most productive uranium mines. An outcrop of torbernite had been seen at Grant's Reef near Rum Jungle by a group of unknowing surveyors in 1869; this same area was explored after World War II and the deposit which ultimately became known as Rum Jungle was found in 1949. The uranium deposit was the property of the Commonwealth, as land owner, and mining commenced on the part of the Bureau of Mineral Resources (as agent for the federal Department of Supply) in 1952. With effect from January, 1953, the mine was worked by Territory Enterprises Pty Ltd, a subsidiary of Consolidated Zinc Ltd, again as agent for the Commonwealth Government.[10] Initially mining was authorised under the *Atomic Energy (Control of Materials) Act* 1946-1952 (Cth) and the *Mining Ordinance* 1939 (N.T.).[11] On the enactment of the *Atomic Energy Act* (Cth) in 1953, that Act became the law controlling mining at Rum Jungle.[12] The mine at Rum Jungle began as a conventional shaft, but in September 1954 became a deep open-cut mine. Quite substantial quantities of ore were recovered[13] and treated on site at a plant which opened in September, 1954. The treatment of ore at Rum Jungle continued until 1971, as did uranium-mining at some thirteen smaller mines in the territory.[14] In 1970, discoveries of further deposits were made at Nabarlek, Ranger (or Jabiru), Jabiluka and Koongarra. The ore concentrations in all these areas are quite high. The deposit at Banarlek is said to contain the highest-grade uranium yet found on earth; the deposit at Jabiluka may be the world's largest.[15] Commercial recovery at Ranger began in 1981, pursuant to an authority granted under s.41 of the *Atomic Energy Act*. Mining at Nabarlek began in April, 1979 pursuant to special mineral lease 94 under the *Mining Act* 1939 (NT) in favour of Queensland Mines Ltd; mining has now been completed and milling is in progress.[16] The reserve at Jabiluka is the subject of a Mineral Lease issued on 12 August 1982 to Pancontinental Mining Ltd and Getty Oil Development Co Ltd, pursuant to the *Mining Act* 1980 (NT). At the time of writing, Koongarra had not been made the subject of a production tenement; however, it is contemplated that it will be mined pursuant to mineral leases granted under the *Mining Act* 1980 (NT).

10. Id. at 8; R. Annabell, *The Uranium Hunters* (1971) 27.
11. See in particular ss 47A, 68(3), and 87A of the Ordinance. The mine site and adjacent area were declared to be prohibited areas for the purpose of the Defence Act 1903 (Cth).
12. The 1953 Act, Part III, substantially re-enacted the 1946 and 1952 Acts. The mining tenement was created pursuant to s.41 of the 1953 Act.
13. AAEC supra n.8; see also I. Hore-Lacy and R. Hubery *Nuclear Electricity* 2nd ed. (1978) and compare G. Blainey *The Rush That Never Ended* 3rd ed. (1978) 337.
14. AAEC supra n.8 at 14, 55-64
15. E.A. Elevatorski, *Uranium Ores and Minerals* (1978) 33; S. Butler, R. Raymond and C. Watson-Munro *Uranium on Trial* (1977) 57; M. Crommelin and R.D. Nicholson *Report on Uranium Mining Laws in the Northern Territory* (1981) 10.
16. Crommelin and Nicholson supra n.15 at 12

Substantial deposits of uranium have also been found in Western Australia. Development of the deposit at Yeelirrie has been approved[17] but commercial recovery has not yet commenced.

The Mode of Mining Uranium

Uranium was first discovered in 1789 and isolated as an element in 1842. The element is well dispersed throughout the earth. At least 104 minerals are known to contain uranium, the most significant of these being uraninite, sometimes referred to as pitchblende. From these sources, there is ultimately derived, after mining and milling, a uranium concentrate (U_3O_8) known as yellowcake.[18] Australia has a significant percentage of the world's "reasonably assured reserves" of uranium-bearing ores.[19]

There are three established techniques of mining uranium: the choice of one technique over another will depend on the location, concentration and geometry of the one body; the nature of the overburden; the minerology and chemical characteristics of the ore and surrounding rock; the groundwater regime; economic factors; and health and safety factors. The two conventional techniques are:

(a) Open-pit mining:

This is the most common technique of uranium-mining in Australia. Many of the deposits in the Northern Territory are amenable to open-pit mining. Over-burden and ore are removed from the surface and from the ensuing pit and carried to adjacent stockpiles.

(b) Underground or Excavation mining:

This technique, also called "stoping", has long been the classic means of mining of most minerals. When stoping is used, the mine workers may work within the stope actually excavating the ore, or outside the stope excavation ("non-entry mining"). Where machines are employed, the stoping may be either of the caving or non-caving variety: caving-mining systems involve the progressive extraction of the ore, leading to the ultimate collapse of the ground above the workings, with the possibility of surface disturbance. In non-caving systems, the roof of the stope is

17. Uranium (Yeelirrie) Agreement Act, 1978 (WA)
18. For a more complete description of the geochemistry and mineralisation concepts of uranium ores, see Elevatorski supra n.15 at 4-12, 44-88, and B.C. Royal Commission Report supra n.2 at Vol I., 48-54.
19. The latest published federal government estimate is that Australia has approximately 16% of the reasonably assured reserves of uranium in the western bloc of nations. Australia, Dept. of Trade and Resources, *Uranium* (1981) 3. Compare the 1980 report by the Department, which assesses Australia's reserves at 18% (p.1), and Butler *et al* supra n.15 at 48 (12.8). Some 80% of these reserves lie in the Alligator Rivers Region in the Northern Territory.

supported (naturally or artificially) to create permanent underground passages.

By whatever means it is extracted, the severed ore is then crushed, graded, milled and treated. Milling is a chemical operation in which the uranium in the ore is dissolved, either by an alkaline leach or sulphuric acid. The solvent removes only uranium, which is then precipitated from the solution, washed and dried.

A third recovery technique is *leaching*. The extraction of uranium by leaching *in situ* involves the use of relatively new technology. A leaching solution, either acidic or alkaline, depending on the chemistry of the orebody, is injected down wells to the "ore horizon", circulated past the orebody, and then carried to the surface, at which point it contains dissolved uranium which is then extracted chemically. This technique was proposed to be employed at the Honeymoon and Beverley sites in South Australia.[20]

The final product of the milling process is called yellowcake.[21] As has been seen, all substantial uranium mines operating in Australia, with the exception of Radium Hill, were supplemented by on-site milling plants.

Dangers Involved in the Extraction and Milling of Uranium Ores

It is agreed that operations of mining and milling of uranium are dangerous to those actually engaged in the work place; the relative and absolute extent of the dangers involved is a matter on which conflicting opinions have been expressed. It is further accepted that the hazards to workers involved in milling uranium are less than any dangers involved in mining uranium ores. Over and above risks involved in any mining or industrial process, uranium-mine and -mill workers encounter risks attributable to the unstable nature of uranium. Unstable elements such as uranium pursue a stable nuclear configuration and, in the course of doing so, decay radioactively, that is, they emit alpha and beta particles and gamma rays. These particles and rays are collectively called "ionising radiation".[22] One of the remote products of the decay of uranium is

20. As to Honeymoon, see Mines Administration Pty Ltd, *Honeymoon Uranium Project, Draft Environmental Impact Statement* (1980) 37-38. For a more general description of uranium-mining techniques, see the B.C. Royal Commission Report supra n.2 at Vol. 1, 133-140.
21. See Fry supra n.2 at 17; Butler *et al* supra n.15 at 57; B.C Royal Commission Report supra n.2 chapter 9.
22. Ionising radiation is electromagnetic or corpuscular radiation capable of producing ions directly or indirectly in passage through matter; in other words, radiation with sufficient energy to separate neutral matter into positive ions and unbound electrons. The injury potential of radiation is put in terms of the ion pairs which it will create in passing through living tissue: K.H. Lokan "The Physical Principles of Radiation Protection" in Australian Radiation Laboratory *Radiation Protection in the Mining and Milling of Radioactive Ores* (1981) (hereinafter, "ARL") Vol. 1, 1, 2; Fry supra n.2 at 3

Radium (Ra_{226}), which is always found in uranium ore. The immediate daughter of radium is radon, which is a gas 7.7 times more dense than air.[23] Radon is accepted as being the source of the major hazard encountered by uranium-mine workers. Although radon is itself very short-lived, having a half-life of only 3.8 days, stocks of it near uranium ores are continually replenished by the decay of radium. While uranium ores are left intact, radon gas remains largely in the ore; however, when the ore is disturbed, as it is during open-cut and underground mining operations, the gas will be released into the atmosphere. Radon tends to accumulate near the surface in still, inversion conditions when no atmospheric mixing is taking place; it also tends to accumulate in badly ventilated buildings and underground mines. Radon itself emits only alpha particles, but its daughter products emit alpha and beta particles and gamma radiation.

The Effects of Exposure to Ionising Radiation:

Ionising radiation can induce both somatic and genetic effects in exposed persons. The nature of the effects induced depends in the first instance on the nature of the constituent emission and, in the second, on the particular tissue or organ of the body exposed; however, the mode of action of the three constituents on human tissues appears to be the same. Alpha particles are claimed to be capable of inflicting severe internal damage to body cells. However, these particles have a range of only a few centimetres in air and an even shorter range in solids; thus, alpha particles impacting on a person are normally absorbed by the outer layers of skin or clothing and constitute a health hazard to internal organs only if they are ingested or inhaled, in which event they can be extremely damaging.[24] The inhalation of air containing alpha-emitting radon daughters is the principal source of radiation dose to the lungs. Ore-dust particles incorporating alpha-emitters may be ingested and inhaled by a uranium-mine worker and may concentrate in particular cells, resulting in radiation damage to organs of the body, including the lung.[25]

Beta particles, like alpha particles, dissipate their energy in matter by producing ionisation, but ionise less intensely. The principal hazard posed by beta-particles also arises if they are ingested or inhaled. However, the hazard is generally less significant than that inherent in alpha-particles. Like alpha-emitters, beta-emitters can become fixed in bone and provoke significant long-term exposure. Beta particles have a range of ap-

23. See Fry supra n.2 at 7-8; Butler *et al* supra n.15 at 58; B.C. Royal Commission Report supra n.2 at Vol. I, 39-55, 64; E.W. Titterton and F.P. Robotham *Uranium· Energy Source of the Future?* (1979) 125.
24. Butler *et al* supra n.15 at 82, B.C. Royal Commission Report supra n.2 at Vol. 1, 46
25. Fry supra n.2 at 16-17

proximately one metre in air and can be arrested by thin sheet metal.[26]

Gamma-ray emission may also result in significant radiation doses to miners. These emissions are very penetrating and can therefore travel from the ore to produce radiation damage deep within the human body.[27]

Thus radiation hazards by mine workers are attributable to three kinds of exposures: first, there is the inevitable exposure to radon gas, released by disturbance of the ore body, and as a result, to the daughter products of radon; secondly, miners may be exposed to external radiation in the form of gamma rays emitted by the ore body; and thirdly, the miners may ingest or inhale ore containing alpha-emitters or beta-emitters which can then be incorporated by the body. The hazards to miners will be greater in the case of underground and open-cut mines than in the case of mines operated by leaching.

Each of these hazards is presented not only by the actual removal of uranium ore from the mine but by the process of milling and by contact with tailings, that is, with the remnants of the ore body after the uranium oxide has been removed by milling. The tailings are the wastes of mining. As has been stated, the predominant practice in Australia has been for milling to take place on or near the mine site, and for the tailings to be stored virtually adjacent to the mill. The net result of the milling process is the division of the radioactive constituents of the ore body into two parts, the yellowcake and the tailings. The commercially valuable commodity, the yellowcake — U_3O_8 — contains U_{234}, U_{235} and principally U_{238}, and is only mildly radioactive. The most radioactive ingredients, quantitatively and qualitatively, are found in the tailings, the waste product of the mining operation. During the milling process there is a risk of external radiation in the mill, which will be highest in the area where the yellowcake is stored. Radon is released into the atmosphere in the mill during the grinding and dissolution stages of milling and radon gas is emitted into the atmosphere through stacks, with associated dangers.[28] Further, there is some risk of injury owing to contamination by substances in the tailings, which are stored more or less indefinitely (and which remain radioactive more or less indefinitely) in on-site dams or beneath revegetated rock and soil cover: the ore has been reduced, by crushing, to a fine, easily dispersed powder and there is a danger of injury through the escape of both windborne radon gas and radioactive dust particles. There is a danger of gamma radiation to persons in the

26. Butler *et al* supra n.15 at 82; B.C. Royal Commission Report supra n.2 at Vol. 1, 46
27. B.C. Royal Commission Report supra n.2 at Vol. I, 47, 61-63
28. Fry supra n.2 at 17-18. It has been suggested that mill workers may encounter increased lymphatic cancer levels due to concentration of uranium and thorium dust in the lymph glands: B.C. Royal Commission Report supra n.2 at Vol. 1, 162.

immediate vicinity of the tailings.[29]

Despite these hazards, it is probably true that uranium mining need not be inherently more dangerous than mining for other substances.[30] The outstanding questions are whether the hazards can in practice be reduced to acceptable levels and whether risks which materialise in injury are properly catered for by schemes of compensation. Before the issues of prevention and compensation are dealt with, it may be convenient to ascertain what kinds of injuries uranium workers may sustain in consequence of their inevitable exposure to some radiation at the mine site or in the mill.

Broadly, these injuries fall into two classes. First, there are somatic injuries, that is, injuries sustained by and becoming manifest in the exposed person. These may be acute or sub-acute. An acute effect of radiation (such as death, irreparable injury to bone-marrow, failure of the gastro-intestinal tract, failures of the central nervous sytem, burns, hair loss and sterility) is produced only by very large doses, doses that would not be encountered at a uranium mine or mill.[31] The sub-acute effects of radiation exposure are more likely to be encountered by mine and mill workers. The most disturbing sub-acute somatic effects of low-level radiation exposure are leukaemia, leucopaenia and cancers, notably thyroid cancer and lung cancer; in addition, however, low-level radiation exposure can cause damage to bone marrow and degenerative diseases such as diabetes and atherosclerosis.[32] The legal problems which these cancers and degenerative diseases will present to injured workers will be considerable; the principal difficulty will lie in establishing a causal nexus between employment at a mine or mill and the injury sustained. These problems are the result of three factors. First, each of the cancers and degenerative diseases referred to is becoming increasingly common among

29. Fry supra n.2 at 18; Butler *et al* supra n.15 at 59. However great are the risks presented to mine workers by the tailings, those risks are exceeded by the hazards presented to users and occupiers of surrounding land: the greatest dangers associated with uranium tailing systems are that radioactive materials will seep from the system into waterways which are a supply either of drinking water for humans or animals or of food for humans or animals, and that the materials will contaminate vegetation which then finds its way into an animal foodchain. This is a particular danger in the Northern Territory, given the nature of the soils surrounding uranium-bearing ores and the very high annual rainfall. Management of tailings at the Rum Jungle and other South Alligator River operations prior to 1971 appears to have been unsatisfactory: see Fry supra n.2 at 19: Butler *et al* supra n 15 at 59; J.M. Costello "Radioactive Waste Management" in *ARL* supra n.22 at 324, 345.

30. Butler *et al* supra n.15 at 59-60. The Ham Commission concluded, by way of comparison, that "current gross risks for uranium miners greatly exceed those for workers at nuclear reactors": supra n.3 at 95.

31 See Royal Commission on Environmental Pollution, Sixth Report, *Nuclear Power and the Environment* (1976) HMSO, Cmnd 6618 (hereinafter the "Flowers Report") at 23; C. Kerr "Health Effects of Nuclear Power" (1980) 7 *New Doctor*, 19; Ranger Uranium Environmental Enquiry, First Report (1976), 85 (hereinafter the "Fox Report"). By a "large dose" in this context is meant a dose of at least 100 rem delivered rapidly to the body.

32. The Flowers Report supra n.31 at 18-21; Titterton and Robotham supra n 23 at 114-120; J. Ward "Uranium — An Unhealthy Prognosis" (1980) 7 *New Doctor* at 9, 12; Stason, Estep & Pierce supra n.4 at 28-35

even the general population and *a priori* may be said to be attributable to any of the countless carcinogens of human manufacture in circulation in the environment. Secondly, while it is accepted in the health professions that even low-level radiation exposure can induce cancer, the causal connexion is still "statistical", that is, a matter of inference based on empirical data rather than proof in an absolute sense. And, thirdly, the cancers have a long latency period so that they may present only long after the worker's employment at the mine or mill has terminated and indeed after the worker has, industrially or otherwise, been exposed to alternative carcinogens.[33]

The second class of injury which may be inflicted by low-level radiation exposure is genetic injury, that is, injury which manifests itself in some deformity or abnormality of the offspring of the person exposed. Low-level radiation interferes with the DNA strands in the cell nucleus; after exposure the DNA will seek to repair itself; on occasions when the autonomous repair mechanisms fails, the genetic tissue is permanently and (if the damage occurs in gene cells within the reproductive organ of the exposed person) heritably mutated. Only a low proportion of genetic damage will be expressed as physical deformities: some mutations will result in the death of the foetus by rendering it "non-viable"; most mutations will be recessive; however, it has been asserted that deformities caused by inherited dominant mutations provoked by radiation exposure can include dwarfism, blindness, shortening of life-span, increased susceptibility to disease, and mental retardation. It must nevertheless be remembered that the evidence for this rests, at this stage, on experiments with and observations of animals.[34] Genetic injuries present the legal system with novel problems: certainly, the worker's compensation schemes will not be available to compensate injured offspring; actions at common law by parents of deformed children or by the offspring themselves will be problematic: the difficulties alluded to in the case of somatic injuries will arise. In addition, given the long latency period of these injuries, compensation may not be recoverable because the employer corporation may have been dissolved. Further, genetic deformities do not bear a particular stamp and cannot therefore be attributed to a particular source. And finally some deformities are traceable in any event to background radiation and are not therefore compensable.

33. See Fry supra n.2 at 2, 8-9; Titterton and Robotham supra n.23 at 116-117; O Axelson "Epidemiology of Occupational Cancer: Mining and Ore Processing" in *Proceedings of the International Symposium on the Prevention of Occupational Cancer* (1982) (hereinafter, "*ILO*") 135, 137; Stason, Estep & Pierce supra note 4 at 86, 498

34 Titterton and Robotham supra n.23 at 114-123; Kerr supra n.31 at 19; Flowers Report supra n.31 at 21-23; J. Rantanen "Chemical and Radiation Carcinogenesis" in *ILO*, supra n.33 at 81, 84-85; Stason, Estep & Pierce supra n.4 at 29, 504.

Protecting Workers From Excessive Ionising Radition

(a) Protective Measures on Foot before 1980

Because of its inherent dangers, mining of all types has attracted special attention from legislatures, resulting in the enactment throughout most of Australia in the early part of the twentieth century of worker health and safety legislation peculiar to the mineral industry. However this legislation was not addressed explicitly to uranium-mining and -milling operations and its adequacy to protect uranium-mine workers from excessive exposure to ionising radiation was questionable. In general it is true to say of industrial safety legislation operative in the mining sphere before 1980 that it was crisis-responsive and that it neither foresaw future developments nor projected itself into a future of technological advancement and of advances in medical science. The groundwork for the cure of this general deficiency in relation to uranium mining came in 1980 with the approval of a new Code of Practice for the protection of uranium-mine and -mill workers; this Code will be analysed in the succeeding section of the paper. In this section there will be a brief treatment of the mining safety legislation operative in those three jurisdictions (South Australia, Queensland and the Northern Territory) where uranium mining took place before 1980.

When uranium mining began in South Australia in 1906, mine safety was controlled by Part IV of the *Mining Act* 1893. That Part authorised inspectors of mines to examine and (if necessary in the interests of health, safety or public amenity) to order the closure of mines. There were no provisions in either the Act or the regulations proclaimed under it for the compulsory medical examination of mine workers.[35] Part IV of the Act was repealed by the *Mines and Works Inspection Act* 1920. Again, this Act did not directly impose any detailed restrictions on mining operations.

Regulation was attained by vesting broad supervisory and policing powers in mines inspectors[36] and by the proclamation of detailed regulations with respect to safety matters.[37] It is not known whether any special precautions were taken in relation to the early operations at Radium Hill and Mt Painter. The health of workers at the post-World War II operations was informally monitored by the South Australian Department of Health by way of the regular administration of blood tests and x-rays.

The initial operations at Mary Kathleen were controlled under the

35. Regulations pertinent to safety were authorised by s.92(3) and s 92(20) Regulations were proclaimed on 28 August, 1907.

36 See, in particular, ss.10 and 11.

37 See s 18 and the Second Schedule The current regulations came into effect in 1966 The only regulations of special note in the present context are regs. 37, 44 and 50 (which relate to ventilation and dust abatement) and reg. 55 (which relates to mining in dangerous conditions)

Mines Regulation Act 1910-1958 (Qld), while the latter phase of operations there was supervised pursuant to the *Mines Regulation Act* 1964-1979. These Acts, like their South Australian equivalent, were concerned largely with inspection of mines and the reporting of accidents.[38] The power of detailed control by way of regulation was delegated to the Governor in Council.[39]

Unless they were exempted by the Administrator from the scope of its provisions, the mining operations at Rum Jungle and elsewhere in the Northern Territory prior to 1972 would have been controlled pursuant to the *Mines Regulation Ordinance* 1939-1962 (NT).[40] The Ordinance was substantially similar to the legislation then in force in Queensland. It imposed no controls specifically on uranium-mining operations and detailed control was effected *via* regulations.[41]

(b) Protective Measures Implemented Since 1980

The single most significant step taken so far in Australia towards adequate protection of uranium-mine and -mill workers from the dangers of excessive exposure to ionising radiation was the approval, in September 1980, of the *Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores*[42] pursuant to the *Environment Protection (Nuclear Codes)*

38. The Act contained the following novel provision:
S.38 "The occurrence of an accident in, on or about a mine shall be *prima facie* evidence of negligence on the part of the manager.
This section does not apply in respect of any action or other proceedings for the recovery of damages in respect of death or injury caused to a person by an accident which occurred in, on or about a mine."
The provision's effect was to import the so-called doctrine of *res ipsa loquiter* from the context of torts into the criminal law, for the purpose of prosecutions under s.65. This provision was re-enacted in the 1964 Act

39. Mines Regulation Act 1910-1958 (Qld.) s.54 (re-enacted in 1964). Sec.57 of the 1910 Act authorised mines inspectors to require mine managers to draw up "special rules" of safety "to take account of local conditions affecting that mine and to be applied in that mine". When prepared and approved, such rules had the force of law: s.57(5). S.57 was re-enacted in the 1964 Act. It is believed that Mary Kathleen Uranium Ltd voluntarily agreed to be bound, in relation to the second phase of mining, by the 1975 Code of Practice on Radiation Protection (as to which, *vide infra* n.42): see R D. Nicholson "Commonwealth and State Controls over Uranium Exploration and Production" (1979) 2 *AMPLJ* 33, 46; A.A. Browne "Recent Developments in the Law Relating to Uranium" (1981) 3 *AMPLJ* 291, 299-301.

40. Sec. 5 authorised the Administrator to exempt mining operations from the reach of the Ordinance, which was repealed in 1977 and replaced by the Mines Safety Control Ordinance 1976 (No. 3 of 1977). The writer has been advised by the Department of Mines and Energy of the Northern Territory that no record of any exemption from the provisions of the 1939 Ordinance exists.

41. Mines Regulations 1939, 1964 (No. 8 and No 14) authorised by s.48 of the Ordinance. See in particular regs. 4-42. It is understood that a medical officer employed by Territory Enterprises conducted regular x-rays and blood tests of mine personnel, in consultation with the AAEC.

42. Code of Practice No. 1 of 1980. The Code superseded and, indeed, substantially reproduced a Code by the same title produced by the Commonwealth Department of Health in 1975 (hereinafter the "1975 Code"). The 1975 Code had no legal status in its own right. However, it was made applicable to all uranium mines in the Northern Territory on 30 June 1978 by force of the Mines (Radiation Protection) Regulations 1978, proclaimed under the Mines Safety Control Act 1976 s.56(2)(d). The 1980 Code is supplemented by Guidelines issued by the Department of Home Affairs and Environment in 1981. The 1975 Code appears to have been the successor of an informal Code agreed on in 1954 between interested Commonwealth and State Ministers. It is unknown whether this Code was adhered to during the pre-1975 uranium projects. All three Codes are reviewed by T.N. Swindon "The Australian Codes of Practice on Radiation Protection in The Mining and Milling of Radioactive Ores" in *A R L* supra n.22 at 192.

Act 1978 (Cth). The Code was declared to come into effect on 31 December 1981. The intended operation of the Code can be explained only in the context of the terms of its parent Act.

The object of the *Environment Protection (Nuclear Codes) Act* 1978 (here inafter the "Nuclear Codes Act") is to make provision, within the limits of the powers of the Commonwealth Parliament, for protecting the health and safety of the human population of Australia, and the environment of Australia, from possible harmful effects associated with "nuclear activities" in Australia.[43] "Nuclear activities" are defined to include the mining and milling of uranium and the construction, operation, or decommissioning of a uranium mine.[44] The Act extends of its own force to the Territories[45] and is expressed to bind the Crown in right both of the Commonwealth and the States.[46] The Act itself does not directly impose any standards or controls on any activity. Rather, the Act authorises the Minister to formulate[47] and the Governor-General to approve[48] Codes of Practice for regulating and controlling "nuclear activities in Australia". The ambit of the potential codes is wide but not unrestricted.[49]

The Codes formulated under the Act are intended to operate uniformly throughout Australia. Of course, given the limitations on the power of the federal Parliament, the Codes cannot in all circumstances operate of their own force on uranium mines within the boundaries of the States, apart from mines conducted on Commonwealth places.[50] Accordingly, the Act draws a distinction between three classes of territory within the Australian land mass. First, as far as Commonwealth places are concerned, the Act provides that the regulations may attract to or exclude from a Commonwealth place a law of the relevant State substantially consonant with a prescribed Code of Practice.[51] Secondly, as concerns federal Territories — including the Northern Territory — the Act authorises regulations giving the Codes the force of law in the Territories.[52] Finally, in relation to the States, the Act authorises regulations empowering the operation of a Code as a law within a State, but only on the request of the Governor of the State, and then only where the regulations would

43. S.3
44. S.4
45. S.5
46. S.6
47. S.7
48. S.9
49. S.9(3)
50. That is, places acquired by the Commonwealth for public purposes within Const. s.52(i).
51. S.11. Compare the operation of the Commonwealth Places (Application of Laws) Act 1970-1973 (Cth) s.4 which attracts State laws to Commonwealth places except to the extent of their inconsistency with Commonwealth laws. Codes of practice are not laws of the Commonwealth for the purposes of Const. s.109.
52. Ss 12, 13(2)(a)(vi)

be independently authorised by a distinct head of federal legislative power.[53]

The Act lastly provides that the Minister may be authorised by the Governor-General to issue orders to abate urgent hazards arising out of a nuclear activity[54] and that regulations may be made for giving effect to the Act.[55] These two powers are quite collateral to the present paper. The 1980 Code of Practice[56] is in operation in the Northern Territory by virtue of regulations proclaimed under the *Mines Safety Control Act* 1978 (NT).[57] It is expected that the Code will be made operative in Western Australia pursuant to the *Nuclear Activities Regulation Act* 1978 (WA), which mirrors the federal Nuclear Codes Act. In South Australia, the substance of the Code will be made applicable pursuant to regulations under the *Radiation Protection and Control Act* 1982. The position as regards Queensland is not clear at present.[58]

The Code itself falls into four parts. Part I prohibits unapproved conducting of

(b) exploratory excavations in uranium mines;
(c) development of a uranium mine;
(d) construction of a uranium mill;
(e) mining or milling operations which may result in the exposure of workers or members of the public to radiation or changes in approved exposure levels;
(f) decommissioning of mines, mills and associated facilities; and
(g) rehabilitation of uranium-mine sites.

However, the Code will not necessarily apply to all uranium mines and mills: subject to a contrary decision by the controlling authority, it applies only to mines and mills from which ores of a prescribed minimum concentration are recovered or recoverable.[59] Part II imposes numerous duties and responsibilities on mine operations, mine managers and mine employees. Perhaps the most important such obligation cast on management is that of ensuring that no employee is exposed to radiation in excess of the standards prescribed by Part III.[60] The most important stan-

53. Ss.12, 13
54 S.14
55 S.15. The only regulations proclaimed at the time of writing were SR 1981 No. 346
56. Since September, 1980, two further Codes of Practice have been approved: Code of Practice on the Safe Transport and Handling of Radioactive Materials (July, 1982) and Code of Practice on The Management of Radioactive Wastes from The Mining and Milling of Radioactive Ores (26 September, 1982).
57. Mines Safety Control (Radiation Protection) Regulations, 1981
58. The Director-General of Mines (Qld) has advised the writer that the 1980 Code of Practice will be adopted in Queensland, with modifications, pursuant to the Mines Regulation Act 1964-1979: see s.54B of the Act, added in 1979.
59 C11 3, 4.
60. C1.5(3)(a). The obligations cast on management by cl.5 and on employees by cl.6 are very particular and no purpose would be served by summarising them here

dards applicable to a worker actually engaged in the mine or mill themselves are fixed by Schedules 1, 3, 5 and 8.[61] The first relates to dose equivalents (that is, to the quantity of ionising radiation to which a worker may be exposed) calculated in rem and sieverts. This standard is that applicable to external radiation in the form of gamma rays emitted by the ore-body. Schedule 3 relates to exposure to radon daughters and thoron daughters. The dose equivalent limit varies according to the organ or tissue exposed; the latter limit is expressed as 4 WLM per annum.[62] From these two sets of basic standards, clause 8 of the Code excludes from calculation:

(i) doses due to natural radiation;

(ii) doses received in the course of medical procedures;

(iii) "doses to lung tissue caused by exposure to alpha-particle radiation from inhaled radon daughters or thoron daughters";[63]

(iv) exposures in the course of "planned special exposures";[64] and

(v) exposures from emergency and accidental exposures.[65]

Schedule 5 relates to the limits on concentration of radio-nuclides in air inhaled or in water consumed by workers. The fourth standard is found in Schedule 8 of the Code which sets the derived limit of radioactive contamination on surfaces with which the worker is likely to come into contact, that is, surfaces likely to bear alpha-emitting radio-nuclides which, as has been seen, may cause injury when ingested or inhaled by a person on dust particles.[66]

To aid in the computation of exposures, management is required to conduct monitoring programs (cl.5(g)) and to measure and assess the various exposures submitted to by each employee (cl.5(x)(i)); further, employees are required to use measurement devices and equipment fur-

61. See cl. 7(1), (3).
62. That is, "working level months". The notions of "working level" and "working level months" (which are related to the radioactivity of radon daughters in mine air before it is breathed) are defined in cl.2. These standards, which are explained more fully in Fry supra, n.2, 9-15, are the accepted levels in Canada and the United States. Their safety is disputed: see n.99 infra and accompanying text.
63. Cl.9(3) and schedule 7(a) set a weekly limit of 0 33 WL on the radon daughter exposure of workers engaged in the mine or mill.
64. The limits, procedures applicable to and exclusions from planned special exposures are set by cll.10, 11, 12 and 13 and Schedule 10.
65. Emergency exposures are controlled by cl.14. The procedures applicable to emergency and accidental exposures are prescribed by cll. 15 and 16 and Schedule 11.
66. See text at n.24 supra

nished by management (cl.6(7)).[67] Finally, it should be noted that records of exposures are required to be made in a form approved by the controlling authority, made accessible to the employee concerned and "retained for such time as is determined by the appropriate authority".[68]

Part IV of the Code deals with the management of radioactive wastes.[69] Part V deals with health surveillance and requires management to conduct medical examinations of each mine or mill worker, free of cost to the employee, at regular intervals and on termination of employment. Certain incidental obligations created by the Code will be alluded to below.

Compensation of Uranium-Mine Workers

As noted above, employment in a uranium mine or mill entails two abnormal kinds of occupational hazards: somatic effects (most notably cancer) and genetic damage. While cancer is not attributable exclusively to radiation exposure, genetic damage probably is. The purpose of this section of the paper is to analyse the extent to which presently existing compensation systems in the jurisdictions in which uranium mining is conducted or is proposed to be conducted in Australia provide adequate remedies for a worker who sustains cancer through radiation exposure or who sustains genetic damage in the course of employment. Both statutory schemes of workers' compensation and the common law will be treated. In addition to substantial compensation, an injured worker may be entitled to sick leave and social security benefits throughout an occupationally-induced illness; however, this paper will be confined exclusively to a study of the employee's rights to compensation for injury rather than to subsidised sick leave.

(a) Workers' Compensation Legislation

The overriding purpose of the workers' compensation legislation is to impose a liability on employers to compensate employees for personal injuries sustained in industrial accidents and for industrially-induced

67. Gamma radiation is reportedly relatively easy to measure. Cumulative gamma and beta radiation to the skin and whole body can be measured either on badges called thermoluminescent detectors (TLD's) or on film badges. Existing levels of gamma radiation can be measured by scintillation-detectors (which employ the geiger-counter principle). Conversely, it is reportedly more difficult to provide dosimetry effective in respect of radon-daughters: see B.C. Royal Commission Report supra n.2 at 61, 66. The "hostile environmental conditions prevailing in the areas of Australia where uranium mining is carried out" militate against the comfort, convenience and effectiveness of the more standard dosimeters: see J F. Boas *et al* "Testing of Ca SO_4:Dy In Teflon Discs as a Thermoluminescent Dosimetry Material for Personal Monitoring of Uranium Mine and Mill Workers" (1981) *Australian Radiation Laboratory*, 2-3; and J.F. Boas *et al* "Thermoluminescent Dosimetry and Assessment of Personal Dose" in *ARL* supra n.22 at 165, 166.

68. C11. 5(t),(x), 17.

69. This must now be read in conjunction with the 1982 Code of Practice on the subject of waste management: see above n.56.

diseases whether or not the employer was "at fault", in that he intentionally or negligently caused or contributed to the accident. Liability is strict but not absolute.[70] Uranium-mine employees in the four jurisdictions being studied in this paper are covered by the ordinary workers' compensation legislation under which recovery of compensation depends on the applicant (that is, the employee or, if he be dead, his dependents) proving the receipt by an employee of a personal injury (including death and disease) arising out of or in the course of employment by the respondent.[71] Compensation is generally recoverable in respect of "incapacity to work", that is, in respect of an injury or disease which prevents the worker from continuing in employment. The legislation draws a distinction, for the purposes of quantification of compensation, between total and partial incapacity.[72]

When an incapacity to work results from an industrial accident or industrially-induced disease, the legislation requires the payment of one or more of the following, in addition to a reimbursement of certain medical, funeral and ancillary expenses which the worker may have incurred:

(b) weekly payments at the statutory rate to the worker to the extent that the incapacity prevents him from engaging in employment;[73]
(c) a lump sum to the worker by way of compounding or redemption of the employer's liability;[74] and
(d) a lump sum to the dependents of the worker on his death.[75]

In practice, the first kind of payment is the most important. However, as noted above,[76] the diseases most likely to be sustained by uranium-mine employees are (a) cancers; (b) degenerative diseases such as diabetes and atherosclerosis; and (c) genetic damage. The last kind of injury is not compensable at all under the legislation because it will involve neither death nor an incapacity to work. Cancer and the degenerative diseases[77] mentioned will be latent for between 1 and 30 years after exposure to

70. The employer's liability is generally qualified or displaced where the worker wilfully inflicts an injury on himself: see Workers' Compensation Act 1916-1982 (Qld) s.9(3); Workers' Compensation Act 1971-1982 (SA) s.9(5); Workers' Compensation and Assistance Act 1981 (WA) s.22; Workmen's Compensation Act (NT) s.7(3).
71. Qld.: s.9(1), (1A); S.A.: s.9(1); W.A.: s.18; N.T.: ss.7(1), 9(1).
72. Qld.: s.14; S.A.: s 51; W.A.: s.24, Schedule One Cl.9; N.T.: Second Schedule Cl. (1A), (1B).
73. Qld.: s.14(B); S.A.: ss.51, 67, W.A.: s.18, Schedule One; N.T.: s.7(1), Second Schedule.
74. S.A.: ss.70, 72, Part III Div. III; W.A.: ss.67, 76; N.T.: Second Schedule cl.(12). This form of payment is not available in Queensland in relation to lung cancers (see the Table following s.13(C)) except at the discretion of the Workers' Compensation Board: s.14B(4), Schedule cl.19.
75 Qld.: s.14(1)(A); S.A.: s.49; W.A.: s.18, Schedule One; N.T.: s.6N and Second Schedule cl.(1).
76 See text at nn. 31, 32, supra.
77. Cancer and the diseases mentioned fall implicitly within the compensble class of injury covered by the legislation: Qld.: s.3; S.A.: s.8; W.A.: s.5 ("disability"). The N.T. Act deems incapacitating diseases to be injuries: ss.6(4) and 9(1).

the precipitating radiation; they may manifest and gain disabling proportions long after the relevant employment has ceased, possibly when the former worker is in retirement. These diseases will ultimately cause the total incapacity and accelerate the death of the former worker. What is the position under the legislation in a case of a worker with this category of injury?

A number of preliminary points must be made. First, the legislation does not prevent the worker or his dependents from suing the employer at common law or, indeed, from suing any other involved actor, at common law, if the accident resulted from actionable fault.[78] Secondly, compensation remains recoverable notwithstanding that the worker has left the employment which caused the injury.[79] Thirdly, while the burden of proof of all factual ingredients of the claim rests for the most part on the applicant,[80] the burden of proof on the issue of causation has effectively been reversed, in the context under discussion, in South Australia, Western Australia and the Northern Territory. In those three jurisdictions, certain diseases, including "pathological manifestations due to radium and other radioactive substances" are deemed to be due to the nature of the worker's employment where the worker was engaged in a described process — in this case, "any process involving exposure to the action of radium and other radio-active substances", unless the employer proves the contrary.[81] Thus, only in Queensland will a uranium-mine worker or his dependents bear the burden of proof of causation of cancer and the diseases mentioned above by exposure to radioactive ores. Cancer of the lung is clearly a "pathological manifestation due to . . . radioactive substances"; the other degenerative diseases mentioned may not necessarily be accepted as falling within the ambit of this phrase.

Three further matters which may well assume importance in cases of applications for compensation by mine workers or their dependents in relation to cancer and degenerative diseases are, first, the apportionment of liability as between successive employers where the worker was engaged sequentially in two or more uranium mines; secondly, the limitation periods operative in cases of latent disease; and thirdly, the relevance of cigarette-smoking on the part of the worker.

78. However, double recovery in relation to the same injuries is prevented by a statutory requirement that the worker repay to the insurer, out of any common law verdict, moneys recovered under the legislation: Qld.: s.9A; S.A.: Part VI; W.A.: ss.86, 92, 93; N.T.: ss. 22, 23. Given the overall inadequacy of payments under the legislation and the limitations on the heads of recovery, common law actions are instituted whenever a reasonable case exists.
79. The statutory periodic compensation ceases to be payable when the worker attains 65 in Western Australia (s.56) and South Australia (s.51(8)).
80. Qld: s.9; S.A.: s.9; W.A.: s.18; N.T.: s.7.
81. S.A : s.94; W.A.: s.44; N.T.: s.9AA. The legislation in South Australia (s.95) and Western Australia (s.45) authorises the Governor to extend the ambit of these provisions to other non-accidental injuries. Part III Div. 3 of the Western Australian Act prescribes special rules and procedures for cases of industrially induced lung cancer.

Where a mine-worker has been employed in more than one enterprise involved in the handling of radioactive substances, a cancer sustained by the worker will not be able to be attributed, in the present state of medical science, to one of those employments as opposed to the other or others.[82] There will, therefore, be no proven link between the disease and a particular employer. What result is predicated by the legislation in this situation? In South Australia, the Northern Territory and Western Australia, given the reversal of the burden of proof in this context, this lack of an ascertainable nexus between the disease and a particular employment will operate, as against the applicant, to the detriment of the last employer, who is deemed by the legislation to be liable to compensate the worker as if the last employer were the sole employer causing or contributing to the injury.[83] In Queensland, on the other hand, where the burden of proof of causation is on the applicant, the lack of a proven link between the mine worker and a particular employment will result in the failure of the claim for compensation.

The workers' compensation legislation, in so far as it fixes limitation periods, appears inadequate to deal justly with the phenomena of latent and degenerative diseases. Indeed, the legislative limitation periods are framed so as to apply logically only to traumatic accidents. In all four States the limitation period (which is six months, except in Western Australia, where it is 12 months) begins to run from "the day of the occurrence of" the injury or the death, as the case may be.[84] Cancers and degenerative diseases do not "occur" on a certain day; their onset is precipitated by exposure to a toxic or carcinogenic substance with which the body cannot cope; the exposure may have "occurred" over a period of days, months, or years. In keeping with the intent of the legislation, it could be argued that, in non-fatal cases, the disease "occurs" when incapacity to work supervenes. To hold that the injury "occurs" on the day (or even on the last day) of exposure would be unconscionable.[85] Injustice can, however, be avoided by a reasonable interpretation of the legislation: in the Northern Territory, South Australia and Western Australia, the legislation provides that late lodgement of a claim is excused by "reasonable cause";[86] and, in Queensland, the statutory tribunal has power to extend or waive the limitation period where

82. See n.33, supra.
83. S.A : s 90; W.A.: s.41; N.T : s.9(1A), (3B). The employer rendered liable by this legislative fiction is given certain rights to claim contribution from other involved employers.
84. Qld.: Schedule cl.4(2); S.A.: s.27; N.T.: s.25; W.A.: s 130.
85. In Cleveland v. Laclede Christy Clay Products Co 129 SW 2d 12, 16 (1939) it was held that for the purposes of a workers' compensation statute limitation period, at least in the case of a latent injury, "injury" means an injury which is reasonably apparent, discoverable, and suspected to be compensable.
86. S.A.: s.27(2)(c); W.A.: s.130(1)(d); N.T.: s.25(1)(ii). In practical terms, s.10A of the Northern Territory Act, which permits the worker to obtain a preliminary declaration of liability, before incapacity supervenes, would not be useful here, where *ex hypothesi* the worker is unaware of the injury.

"reasonable cause" is shown.[87] These provisions should be interpreted so that the latency of an industrially-induced disease is invariably a "reasonable cause" for failure to present a claim and that the "cause" continues until such time as the worker is aware, or ought reasonably to be aware, that his disease is both incapacitating and compensable.[88]

What evidence there is indicates that a worker who smokes regularly during employment at a uranium mine is five times more likely than a non-smoker to contract lung cancer through radiation exposure.[89] Despite that the Code of Practice forbids smoking in certain areas,[90] it is suggested that smoking by a worker whether in a designated area or not could not, as a matter of law, defeat an otherwise maintainable claim. Mere contribution to an injury is not tantamount to wilful self-infliction of an injury and is, therefore, incapable of displacing the statutory liability of the employer.[91]

A final matter worthy of comment in this context is the effect of corporate dissolution on a workers' compensation claim. Mining companies, or at least operator companies, are often incorporated to manage a single project; at the conclusion of the relevant project the affairs of the company may be wound up and it can then be dissolved and struck off the register of companies. It then ceases to be a legal person and can no longer sue or be sued nor can a statutory claim for compensation be made against it. In this event, the legislation authorises the worker to make a claim either directly against a statutory fund or against the insurer in substitution for the employer as the respondent in the action, and the action proceeds accordingly.[92]

(b) Common law claims

A worker (or, in the case of a fatal industrial disease, the worker's dependents), if dissatisfied with the quantum of compensation recoverable under the workers' compensation legislation, may institute common law actions for damages for negligence or (in the case of fatal diseases) actions pursuant to statute for damages equivalent to the economic loss attributable to the wrongful death of the worker against persons who, in

87. Schedule cl.4(2)(b)

88 This is the result argued for in a host of American articles on the subject: see e.g. A. Favish "Radiation Injury and the Atomic Veteran" (1981) 32 *Hast.L.J.* 933; J.R. Burcat "Uncompensated Victims of Low Level Radiation" (1979-1980) 15 *Forum* 847; Note: "Compensating Victims of Occupational Disease" (1980) 93 *Harv.L Rev.* 916; J.A. O'Hare "Asbestos Litigation" (1978) 7 *Ford. Urban L.J* 55; M.E Solomons "Workers' Compensation for Occupational Disease Victims" (1977) 41 *Albany L.Rev.* 195.

89. Fry supra n.2 at 13-14; B.C. Royal Commission Report, supra n.2 at Vol. 1, 79. Regular cigaratte smoking by uranium-mine workers appears to have the incidental effect of reducing the latency period of lung cancer.

90. Cl 6(9); cl.5(3)(o).

91. See text at n.70, supra.

92. S.A.: s.17; Qld.: s.9(1) and Schedule, cl.4 (see also s.9A(2A); W.A. s 173; N.T.: s.9B.

an actionable sense, caused or contributed to the disease. The possible grounds of such dissatisfaction are many. First, the workers' compensation legislation requires no compensation to be paid for pain and suffering endured by the worker, for loss of amenity, for sterility, for shortening of life, for increased susceptibility to disease or for loss of a provable expectancy (apart from the disease) of improved earnings in the future; nor does it require complete reimbursement of the workers' expenses, or a complete indemnity against lost earnings. Secondly, as against those dependent on the worker, the capital sums payable under the statutes on a disease-induced death will be, in most cases, significantly less than amounts recoverable under an action based on the wrongful death statutes deriving from *Lord Campbell's Act*.[93] Thirdly, persons physically injured by reason of a worker's exposure to radioactive substances (for example, it is possible, although unlikely, that a member of the worker's household will be injured by inhaling or ingesting radioactive dust carried home on the worker's person or clothing) have no action under the worker's compensation statutes and must rely on the common law. Finally, descendants of a worker whose genetic make-up is adversely affected by radiation exposure of the ancestor-worker have no action under the workers' compensation statutes and they, too, must rely on the common law. Peculiar problems which may arise in these various classes of actions for damages arising from radiation exposure will now be considered.[94]

Proof of Fault

With one exception,[95] a person suing for damages in respect of personal injuries accidentally inflicted on a worker must prove that the accident was a foreseeable result of the negligent conduct of the defendant or his agents. This is true whether the plaintiff is the worker or his dependents or descendants. The employer is liable only if he did not discharge the standard of care required by the law in the circumstances. It is conventionally said that the employer's duty of care to employees

93. Qld.: Common Law Practice Acts 1867 s.12; S.A.: Wrongs Act 1936 Part II; W.A.: Fatal Accidents Act 1959, s.4; N.T.: Compensation (Fatal Injuries) Act 1974, s.7. These provisions entitle the plaintiff dependent to succeed if there is proof of economic loss consequent on the death of a person, the death being attributable to the "wrongful act, neglect or default" of the defendant.

94. The only kinds of action which will be considered in this section are those maintainable against the employer. It is possible that personal injuries attributable to uranium mining will generate a governmental liability at two levels: on the one hand, it may be argued that a government was negligent in proclaiming a safety code or safety or safety standards which were inadequate to their purpose. Such an action has no precedent in the common law world, so far as the writer is aware. On the other hand, it could be argued that government agents were negligent in supervising a code and in enforcing safety standards. An action on this basis is clearly maintainable: Dutton v. Bognor Regis UDC [1972] 1 QB 373; Anns v. Merton London Borough Council [1978] AC 728; Commonwealth v. Turnbull (1976) 13 ACTR 14; Hull v. Canterbury M.C. [1974] 1 NSWLR 300; Blaber v. United States 332 F.2d. 629 (1964). Compare McCrea v. White Rock (1974) 56 DLR 3d 525.

95. The exception relates to the action for breach of statutory duty, which is considered below.

has three principal aspects: the duty to provide a safe system of work, safe premises and safe plant.[96] The standard of care and its particular details are ordinarily fixed after the event by the tribunal of fact hearing an action for compensation. However, the measure and quality of the standard of care in the context under discussion must now be regarded as fixed, at least in part, by reference to the Code of Practice which, together with the guidelines under it, imposes detailed and specific obligations on employers.[97] It is, in some respects, analogous to the better known safety codes proclaimed under the Factories, Shops and Industries legislation, the Scaffolding and Lifts legislation and the Mines Regulation and Inspection legislation. Even if the Code is not legally binding on a particular employer (because not in force in the relevant jurisdiction), proof of a material breach of its prescriptions and standards would probably be some evidence of negligence.

Does the converse of this proposition hold true, that is, does compliance with the Code necessarily absolve the employer or amount to a discharge of the obligation to take due care? The decided cases on other industrial safety charters indicate that this question must be answered in the negative.[98] Two particular points in support of this conclusion can be made in relation to radiation exposure through uranium mining: first, the standards of exposure fixed by the Code are maxima and not minima and they are not universally accepted as safe;[99] and secondly, all employers in hazardous industries have a duty to keep abreast of technological advances and scientific progress and, if new technology or fresh information becomes available indicating that the Code's prescriptions are or may be inadequate, the employer would be obliged to make the appropriate adjustment to internal safety procedures,[100] even in advance of formal variations to the Code.[101]

96. Wilsons & Clyde Coal Co. Ltd v. English [1938] A.C. 57, 78; Wilson v Tyneside Window Cleaning Co. [1958] 2 Q.B. 110, 116.
97. J.G. Fleming *The Law of Torts* 5th ed. (1977) at 117-119, 122-123.
98. Mercer v. Commissioner for Road Transport (1936) 56 C.L. R. 580, 589, 602-603; Paris v. Stepney Borough Council [1951] A.C. 367; Wise Bros. Pty Ltd v. Commissioner for Railways (1947) 75 C.L.R 59, 72; Heck v. Berryllium Corp. 424 Pa. 140, 226 A 2d. 87 (1966).
99. Note the concluding phrase of cl.5(3)(a) and see, for example, NIOSH Study Group Report, *The Risk of Lung Cancer Among Underground Miners of Uranium-Bearing Ores*, 30.66.1980, ii 9, 34-36, the evidence reviewed and conclusions reached in the B.C. Royal Commission Report supra n.2 at Vol. 1, 80-83; the Ham Report, supra n.3 at 94-95, W J. Nicholson "The Dose and Time Dependence of Occupational Cancer" in *I.L.O.* supra n.33 at 44, 63; C.B. Kerr "Health Consequences of Environmental Pollution by Ionising Radiation" (1981) *Med J Aust* 1:685.
100. See e.g. Marsh Wood Products Co. v. Babcock & Wilcox Co. 204 N.W. 392 (1932); Rakowski v. Raybestos-Manhattan Inc. 68 A 2d. 641 (1949). In this connection, too, the concluding words of cl.5(3)(a) of the Code are very pertinent
101. Environment Protection (Nuclear Codes) Act 1978 (Cth) s 9(1)(b) authorises variations to approved Codes.

Breach of Statutory Duty

In the Northern Territory, the Code of Practice has, indirectly, the force of law.[102] It is therefore possible that a breach of the Code by an employer which results in a personal injury to an employee will be held to be an actionable wrong whether or not the employer was negligent. The Regulations which apply the Code in the Territory impose penal sanctions on their breach.[103] They do not expressly create a civil liability. Clearly though, the Regulations have been proclaimed for the benefit of the workforce and, despite the express prescription of a criminal penalty, courts in the Territory would be bound to approach the Regulations with a presumption that the legislature intended impliedly to create a private right, in a worker injured by breach of the Code, to recover damages for that injury, even if no negligence in the ordinary sense was associated with the breach.[104] In other words, the Regulations adopting the Code impose a strict liability on employers operating a mine pursuant to the Code.

Causation

Whatever the nature of the action against the employer, whether direct or derivative, it must be proved by the plaintiff that the employer's negligent or other wrongful act or default caused the injury complained of. Whether the injury complained of be leukaemia, cancer, degenerative disease or genetic damage, the problem for the plaintiff[105] will be the same: those pathological manifestations do not incriminate the phenomena, substance, exposure or chemical which precipitated or initiated them. The plaintiff must prove both an irradiation and compensable physical injury connected with it. Proof of irradiation may, to some extent, be supplied by inference from the mere fact of engagement in a mine or mill; more direct proof will be available *via* the records of exposures required to be kept by the Code of Practice.[106] However, the "anonymity" of the precipitating agent militates against proof of a connection between irradiation and a particular injury. Moreover, where an injured worker has been engaged in more than one uranium mine or mill, or employed in a second workplace where exposure to carcinogens

102. Mines Safety Control (Radiation Protection) Regulations 1981. As to imminent projects in South Australia and Western Australia, see cl.10 of the Roxby Downs Indenture and s.8 of the Roxby Downs (Indenture Ratification) Act 1982 (S A.) and cl 13 of the Uranium (Yeelirrie) Agreement.
103. Reg. 6.
104. O'Connor v. S.P. Bray Ltd (1937) 56 C L.R. 464, 477-478, 485-486, H.H Glass, M.H McHugh and F.M. Douglas *The Liability of Employers* (1979) Ch VII, VIII; Fleming supra n.97 at 119-133, 485.
105. A more complete treatment of the problems of proof of causation in this context is found in Estep, Stason and Pierce supra n.4 at 360-424.
106. C11.5(3)(t), (x), (z), (dd), (ee)

or toxic chemicals was likely, it will be impossible, given the present state of medical knowledge, to attribute a disease to irradiation in a mine or mill. Even where the injured worker has been engaged in only one hazardous enterprise, it may be difficult to obtain convincing evidence that the injury is traceable to radiation in a mine or mill rather than to a number of putative competing causes, such as exposure to diesel fumes, cigarette-smoking, clinical x-rays, background radiation, non-industrial exposure to toxins or carcinogens and so forth. This proposition holds true, of course, in other industrial contexts and calls for immediate parliamentary attention.[107]

In this scenario of nescience, the rules of the common law as to joint and several tortfeasors will not assist the plaintiff. The basic principle of the law is that a defendant is liable only for damage caused by his own acts.

The mere fact that two or more persons may, through identifiable but unrelated acts of negligence, have caused, contributed to or compounded an injury (specific aspects of which cannot be attributed to a specific defendant) does not render those persons jointly liable to the plaintiff.[108] Nor is there any authority in the four jurisdictions being discussed or any basis in general principle for permitting consolidated trials of actions against successive employers or independent tortfeasors[109] and therein reversing the burden of proof.[110] In general, the plaintiff's inability to prove, in his own case in chief, a causal connexion between his injury and the wrongful act or default of a particular defendant entitles the latter, at common law, to a verdict in his favour without the need for the defendant to go into evidence.[111] Steps that may be taken by the Parliament in order to alleviate these difficulties are alluded to in the conclusion.

Pre-Conception Injuries

As has been stated,[112] exposure to ionising radiation can precipitate

107. A great number of American journal articles written over the last 30 years deal with these general questions. See e.g. J.A. O'Hare "Asbestos Litigation" (1978) 7 *Ford. Urban L.J* 55; Page and Sellers supra n.3; R.R. Monson "Effects of Industrial Environment on Health" (1978) 8 *Env Law.* 663; M.E. Solomons "Workers' Compensation for Occupational Disease Victims" (1977) 41 *Albany L Rev.* 195; A. Favish "Radiation Injury and the Atomic Veteran" (1981) 32 *Hast.L.J.* 933; J.R. Burcat "Uncompensated Victims of Low-Level Radiation" (1979-1980) 15 *Forum* 847; J. Elder "Nuclear Torts" (1975) 11 *New Engl.L Rev.* 111.

108. Bonnington Castings Ltd v. Wardlow [1956] 1 All E R. 615, 618-619; G.L. Williams, *Joint Torts and Contributory Negligence* (1951), 1, 20; Fleming supra n.97 at 237-239.

109. S.A.: S.C.R. 0.49 (in conjunction with R.S.C. 0.15 r.4 (Engl.); W.A.: S.C.R. 0.18 r.4, 0.83; Qld.: R.S.C. 0.3, r.5, 0.4 r.7, 0.61 r.5; N.T.: S.C.R. 0.51

110. Only in very special fact situations can the burden of proof between a plaintiff and two or more *alternative* putative tortfeasors be reversed: Cook v. Lewis [1951] S.C.R. 830; Summers v. Tice 199 P.2d. 1 (1948); Willis v. Allen [1923] S.A.S.R. 146.

111 Metropolitan Ry Co. v. Jackson (1877) 3 App.Cas. 193; contrast Menzies v. Australian Iron and Steel Ltd and Hill (1952) 52 S.R. (N.S.W.) 62, 64-65 and Hummerstone v. Leary [1921] 2 K.B. 664 where two defendants were sued in respect of a *single* transaction.

112. See text at n.34 supra.

damage to human gene material, including genes in the sex cells, damage which can find expression in the physical impairment or deformity of descendants of the exposed ancestor. While the probability that genetic damage induced by low-level ionising radiation will cause serious disabilities in humans is remote, it is interesting to speculate on the response which the law will make to claims for damages for physical injury and economic loss proved to have arisen out of such damage. Such claims will generally be either by or on behalf of the descendant for damages for physical injury in respect of the deformity, or by the parents of a deformed child for damages for economic disadvantage or physical injury through distress. Actions of the latter kind are already becoming common.[113] Attention will be paid here to the question whether actions of the former character are maintainable at common law. No such action has yet been the subject of a reported decision in any Commonwealth country,[114] and, accordingly, the success or failure of such an action is a matter of extrapolation from established principle.

The common law has recently come to accept that pre-natal injuries, that is, injuries sustained by a foetus, are actionable. In the Commonwealth countries, the action is contingent on the live birth of the child.[115] The chief objection in principle to claims for pre-conception injuries is that, at the time of the defendant's wrongful act, the plaintiff was not a legal person and could not, therefore, have been owed a legal duty by the defendant. This objection applied equally in pre-natal injury cases, given that the law deems legal personality to accrue at birth; the objection failed in the pre-natal cases and it should, by parity of reasoning, fail in the pre-conception injury cases. In the pre-natal injury cases, it has been decided that a breach of the duty to take reasonable care may be sued on by a person to whom that duty could not have been owed at the time of the breach (because the plaintiff had no legal personality) and that it is sufficient that the plaintiff be a member (albeit non-existent) or subsequently become a member of a class of persons (all or some of whom may be non-existent when the breach of duty occurs) who might

113. See e.g. McKay v. Essex Area Health Authority [1982] 2 W.L.R. 890; Fleming supra n.97 at 161; Law Commission *Report on Injuries to Unborn Children* (1974), Report No. 60, Cmnd 5709, para. 7-8, 27; Sciuriaga v. Powell (1979) noted at (1981) 44 *Mod L Rev* 215.

114. Renslow v. Mennonite Hospital (1976) 351 NE 2d 870 and Jorgensen v. Meade Johnson Laboratories Inc. 483 F. 2d 237 (1973) where it was held that the common law permits recovery for pre-conception injury.

115. Watt v. Rama [1972] V.R. 353, 360; Duval v. Sequin (1973) 40 D.L.R. 3d 666; Montreal Tramways v. Leveille [1933] 4 D.L.R. 337; Pratt v. Pratt [1975] V.R. 398; Moate v. Mercantile Mutual Insurance [1977] Tas. S.R. 46; P.F. Cane "Injuries to Unborn Children" (1977) 51 *A.L.J.* 704 and the articles cited in n.3 thereof; as to the more complex position in the United States, see F.J. Hartye "Tort Recovery for the Unborn Child" (1977) 15 *J of Fam Law*. 276. As to the United Kingdom, see Congenital Disabilities (Civil Liability) Act 1976 ss.1(2)(a), 1(4), 3; Royal Commission on Civil Liability and Compensation for Personal Injury *Report* (1978) Cmnd. 7054, Vol. 1, 310-311 (the "Pearson Report").

foreseeably be injured in consequence of the defendant's conduct.[116] The gist of the cause of action for a pre-natal injury, it has been held, is *the birth of the plaintiff with a disability* attributable to the defendant's careless conduct.

The physical difference, at the moment of the defendant's wrong, between a plaintiff alleging an orthodox pre-natal injury and a plaintiff alleging a pre-conception injury, is obvious. The former is a discrete organism, albeit dependent on the mother's body. The latter is the subsequent fruit of the conjunction either of two sex cells in existence at the moment of the defendant's wrong or of two sex cells created (by the natural mitotic process) by sex cells in existence at that moment; at the time of the wrongdoing, the pre-conception plaintiff is in no sense a discrete organism. The plaintiff is the product of two unidentifiable cells (or of their daughter cells), one of which is damaged by ionising radiation in a heritable respect while part of the body of an ancestor of the plaintiff.

Nevertheless, if one accepts the reasoning in *Watt* v. *Rama*,[117] this radical biological difference, at the moment of the wrongdoing, is immaterial in law. An explicit premise in the reasoning in that case is that every conceived human being has a right to be born free of disabilities attributable to the prior fault of the defendant.[118] The recoverability as a matter of law of damages for pre-conception injuries will depend on whether the court regards the damage as reasonably foreseeable by the defendant at the time of the wrongdoing. This is purely a question of judicial policy.[119] Naturally, problems of proof, including those previously alluded to, militate in fact against successful actions for pre-conception injuries.[120]

Voluntary Assumption of Risk

In general, a person who voluntarily assumes the risk of an injury has no action against the person inflicting the injury. However, at least in

116. Watt v. Rama supra n.115 at 360, 363-365. This approach is supported by the advice of the Judicial Committee of the Privy Council in Grant v. Australian Knitting Mills Ltd [1936] A.C. 85, 104 and by the reasoning in Chapman v. Hearse (1961) 106 C.L.R. 112, 120. See also Law Commission Report No. 60 supra n.113 at para 75-80, and Kosby v. Trustees of Sisters of Charity [1982] V.R. 961, 969-970.
117. Supra n.115
118. Id at 377
119. Dorset Yacht Co. Ltd v. Home Office [1970] A.C. 1004, 1025, 1058; Junior Books Ltd v. Veitchi Co. Ltd [1982] 3 W.L.R. 477. A contrary conclusion on the question of recoverability of damages for pre-conception injuries was reached in H. Street and F.R. Frame, *Law Relating to Nuclear Energy* (1966) 36-37. As to the position in the United States, see Stason, Estep and Pierce supra n.4 at 222-224; S.D. Estep and E.H. Forgotson "Legal Liability for Genetic Injuries from Radiation" (1963) 24 *La L Rev.* 1; and C.L. Moore "Radiation and Pre-Conception Injuries" (1974) 28 *Sw.L.J.* 414.
120. Estep and Forgotson supra n 119 at 36, 44-46 reached the conclusion that a pre-conception genetic injury will never be able to be connected with a low-level radiation exposure. See also the Pearson Report supra n.115 at 304-305.

the industrial context, proof by the defendant of an assumption of the risk of injury on the part of a plaintiff is, in the overwhelming majority of cases, a practical impossibility: the defendant must show that the plaintiff, having full knowledge of the risk, has agreed (expressly or impliedly) to waive his right to redress for injuries materialising from the risk. In other words, the plaintiff must be shown to have assumed not only the physical risk of injury but also the legal risk of harm.[121] Thus, the mere fact that a mine worker entered or remained in a mine or mill despite knowledge of the theoretical risks of exposure to ionising radiation will not defeat a claim in negligence by the worker against the employer. The same would be true of a mine worker who, under direction, enters an open-mine site during inversion conditions or enters a shaft while ventilation equipment is malfunctioning or inoperative, so that his intake of radon will be higher than normal, even if he has actual knowledge of the dangers inherent in his conduct.

There is equally little reason to doubt that the plea of voluntary assumption of risk would fail in respect of injuries which can by some means be attributed to one or both of two irregular activities contemplated by the Code of Practice, that is, the "planned special exposure" and the "emergency exposure". Generally, exposures of workers to radiation above the prescribed intensity or limit are prohibited by the Code.[122] The prohibition is relaxed only in two situations, namely those two irregular exposures referred to above.[123] A worker's voluntary or directed participation in either of these exposures, even if "danger money" was agreed to be payable, could not reasonably be held to be an assumption of the legal risks of injury, given that the exposure is undertaken for the benefit of the enterprise and that the Code indicates an intention, not that the employer's prescribed and implied obligations shall be diminished in the course of these procedures, but rather that the employer shall take additional precautions for the safety of the worker involved.[124]

Contributory Negligence

In two classes of case employment at an uranium mine or mill may generate unusual arguments that a worker complaining of an injury attributable to ionising radiation contributed in a material sense to the in-

121. Smith v. Baker [1891] A.C. 325; Bowater v. Rowley Regis Corp [1944] 1 K.B 476, 479-480.
122. Cl.5(3)(a), schedules 1, 3.
123 A planned special exposure is controlled by c11 10, 11, 12. The Code contains no criteria indicating when such an exposure may be proper and the decision to direct a planned special exposure is that of the operator. The consent of the statutory supervising authority is not required. Schedule 10 sets a limit on the radiation exposure permissible in this kind of procedure. A worker other than a fertile woman (cl.12(b)) can be directed to take part in a planned special exposure. On the other hand, the worker's participation in an emergency exposure must be voluntary and the Code spells out the criteria by reference to which the operator must act· cll.14, 15; 6(10).
124. Compare Fleming supra n.97 at 288-289.

jury. As will be seen on analysis, the first class of case, that of the cigarette-smoking worker, gives rise not to problems of contributory negligence but rather to problems of causation. The second class of case may present genuine problems of contribution.

One of the potential consequences of the inhalation of radon gas is lung cancer. It is notorious that cigarette-smoking alone can cause lung cancer. Respiratory cancer rates among uranium miners who smoke are significantly higher than rates among non-smokers.[125] In recognition of this, the Code of Practice requires the operator and manager of each mine or mill to which the Code applies to set aside locations, in on-site areas of less intensive radiation risk, where smoking may be indulged in by workers.[126] As a corollary, the Code prohibits employees from smoking in areas where radon is likely to be more abundant than is desirable.[127]

Now, lung cancers do not identify their precipitating agent. A lung cancer sustained by a mine or mill worker who has regularly indulged in cigarette-smoking cannot be traced positively either to radiation-exposure or to cigarette-smoking. Thus, except perhaps in Western Australia,[128] a plaintiff mine-worker who has smoked (or those suing in a derivative action based, for example, on the Australian equivalents of *Lord Campbell's Act*[129] in respect of the death of a worker who has smoked) will fail altogether in a common law (or derivative) action because unable to prove a nexus between the employment and the injury. The apportionment legislation[130] will not be applicable because the injury cannot be shown to be the "result" of or "due to" the fault of the employer as opposed to the voluntary, private conduct of the worker in smoking.

Genuine instances of contributory negligence may arise where, for example, a mine or mill worker commits clandestine breaches of an obligation imposed on him by the Code by, for example, persistently ignoring warning signs, by failing to use protective equipment provided by the operator, or by removing a dosimeter while in a place of exposure so as to keep his readings low and avoid being transferred to other duties.[131] In theory, all three breaches may constitute contributory negligence on the part of the employee to the extent that they increase

125 See text at n.89 supra.
126. Cl.5(3)(o).
127. Cl.6(9).
128. As to Western Australia, see Fleming supra n.97 at 251 n.3a.
129. See the statutes cited in n.93.
130. Wrongs Act 1936-1975 (S.A.) Part III and especially s.27a; Law Reform (Tortfeasors Contribution, Contributory Negligence and Division of Chattels) Act 1952 (Qld.) Part III, s.10; Law Reform (Contributory Negligence and Tortfeasors' Contribution) Act 1947 (W.A.) s.4; Law Reform (Miscellaneous Provisions) Act 1956 (N.T.) Part V. Actions under the wrongful death statutes (set out at n.93) are subject to the operation of the contribution legislation.
131. Cll.6(2), (6), (7). Where a worker's exposure over a certain time exceeds the desired limits, the employer has an obligation to transfer the worker to other duties: cl.5(3)(aa), (cc).

the exposure of the worker and the risk of injury to him.[132] However, against this it can be argued that the employer has an obligation to provide supervision of the workforce to prevent breaches of this very kind[133] so that the employer remains liable at law for injuries resulting from these breaches. The breach in relation to the measurement device may, however, have more unfortunate consequences for the worker in a common law claim, and grave consequences for his dependents, in a *Lord Campbell's Act* action. The exposures registered on the dosimeter are translated by the employer to the worker's statutory records. The dosimeter is not required to be delivered to or inspected by the supervising authority. Indeed, in the case of thermoluminescent dosimeters, the method of reading involves the destruction of the information on the dosimeter. If there are low or no measurements on the dosimeter, the exposure records will show only insubstantial exposures. While there is no proven linear relationship between exposure and cancer, the lower the recorded exposure the less likely it is that radiation in the mine or mill, as opposed to some extraneous factor (such as smoking), will be accepted as having caused the cancer complained of.

Limitation Periods

In the introduction to this paper, it was predicted that two of the classes of injury potentially arising from exposure to ionising radiation which may prove problematic for the law are injuries that are described somewhat elliptically as "deferred" and "contingent". A deferred injury is one not manifesting within the standard legal limitation periods of three or six years after either the defendant's wrongdoing or the act (in this case, the irradiation) which ultimately produces the injury. A contingent radiation injury can be said to have occurred when irradiation of the worker takes place to such an extent that pathological manifestations are likely, but not certain, to accrue: the symptoms of injury are contingent on factors such as the age and genetic makeup of the exposed person, and subsequent events. The latter class of injury tends to merge to some extent with the former if one takes it as given that, for the purposes at least of the tort of negligence, no interference with the body is actionable unless it produces clinically assessable physical injury. Thus, a contingent injury (such as excessive irradiation) cannot be litigated until there are physically observable and therefore compensable consequences, such as

132. Fleming supra n.97 at 251, 257. Where the action is based on breach of statutory duty, the contribution legislation (set out at n.130) can, in the absence of provision to the contrary, be applied so as to reduce the quantum of the verdict: Piro v. W. Foster & Co. Ltd (1943) 68 C.L.R. 313.

133. See cl.5(3)(f) and Henwood v. M.T.T. (1938) 60 C.L.R. 438, 463, Wingfield v. Ellerman's Wilson Line Ltd [1960] 2 LL.Rep. 16, 23.

cancer.[134] These consequences may not manifest themselves until well after the irradiation and hence, at least for the purposes of negligence, the contingent injury becomes a deferred injury.

What rules apply to injuries which do not become compensable for 15 or 30 years after either the defendant's act or the physical contamination of the plaintiff or worker? In the four jurisdictions laws of which are being treated in this paper, actions for damages for personal injuries (including disease) are, in general, barred three years[135] after the date on which the cause of action "arose" or "accrues".[136] Does a cause of action in negligence or for breach of statutory duty arise when the injury (the excessive irradiation) occurs or when the injury results in an impairment? There are authorities both ways, but in general the rule is that the cause of action arises when the damage is done, not when it is discovered.[137] That this rule may become unworkable is demonstrated in the case of an irradiated worker whose life expectancy or actual life is shortened by radiation exposure: the claim would probably fail for want of evidence that the radiation caused the shortening, but what would be the result when evidentiary hurdles are overcome?[138] Fortunately this question is now largely academic except in Western Australia, for in Queensland, South Australia and the Northern Territory, the court has power under the Limitation Acts to extend the limitation period in the case of latent diseases, that is, in cases where the plaintiff has no knowledge of a material fact (compensable injury) entitling him to bring an action.[139]

134. *Contra*, Coover v Painless Parker, Dentist 286 P. 1048, 1050 (1930) where it was held that a radiation exposure can be litigated without waiting for pathological manifestations if a physical impairment is likely to result. In conjunction with the "once and for all rule" (Fetter v. Beal (1701) 1 Ld. Raym 339, 692) this reasoning could reduce compensation-litigation to the status of an overt lottery. Cancers are paradigmatic contingent diseases. While the exact mechanisms involved in the transmutation of "normal" cells to cancer cells are not fully known, it appears that the process of transmutation involves an interplay between endogenous and exogenous factors and occurs in two phases: *initiation*, which is an irreversible process produced by exposure to a carcinogen, and which gives rise to latent cancer cells which remain receptive to the second and independent phase, and *promotion*, in the course of which the dormant cancer cells become malignant. Thus, irradiation and its consequent ionisation of cells is the initiation of an injury which will not become manifest (and therefore compensable) unless and until the person is exposed to a promoting agent. See E. Mastromatteo "Current Concepts in Occupational Carcinogenesis" in *I L O* supra n 33 at 26.
135. In Western Australia the period is six years: Limitation Act 1935, s 38(1)(c)(vi).
136. Limitation of Actions Act 1936-1975 (S.A.) s.36; Limitation Act 1981 (N T.) s 12(1)(b); Limitation of Actions Act 1974 (Qld.) s. 11.
137 Compare Backhouse v. Bonomi (1861) 9 H.L.C 503; Higgins v. Arfon B C. [1975] 2 All E.R. 589; and Cartledge v. E.Jopling and Sons Ltd [1963] A.C. 758 with Watson v. Winget Ltd [1960] S L.T. 321 and Clarkson v Modern Foundries Ltd [1957] 1 W.L.R. 1210.
138. This class of case is discussed in Stason, Estep and Pierce supra n.4 at 270ff.
139. S A.: s.48; N.T. s.44; Qld.: ss.30, 31. This power cannot be invoked in respect of worker's compensation claims. As to the exercise of the power in favour of an adult with a latent injury and a child complaining of a pre-conception injury, see Kosky's case supra n.116.

The cause of action for the wrongful death of a worker arises on the death and is in general barred three years from the date of death, subject, again, to the power of the court to grant an extension.[140]

The cause of action of a person complaining of physical injury due to genetic damage to an ancestor (that is, a pre-conception injury) arises on the birth of the plaintiff.[141] However, time does not run against an infant[142] and an action for a pre-conception injury can, therefore, be instituted at any time within three (or, in Western Australia, six) years after the attainment of majority.

Thus, limitation periods have the potential to work injustice only in Western Australia, and then only in actions by the injured worker himself, because of the lack of power in the court to extend the applicable limitation period.

Conclusion

The theme of this Congress has been "Resources and Responsibility". The particular resource at the centre of this paper has been Australia's extensive reserves of uranium. The issue addressed has been whether our legal system discharges society's responsibility to the workforce engaged in operations of mining and milling uranium. That public, collective responsibility, which has been compelled by historical circumstances to supersede the private responsibilities of mine- and mill-owners and operators, has two aspects: first, the duty to erect adequate safeguards to ensure that the peculiar hazards faced by uranium workers (that is, hazards of ionising radiation) are contained within limits which are as low as are reasonably achievable; and secondly, the duty to ensure that, if those safeguards prove ineffective, then just, equitable and immediate compensation will be available to injured workers.

It cannot be said that the first limb of this duty was discharged in relation to the operations at Radium Hill, Rum Jungle and the first phase of operations at Mary Kathleen. The law imposed on those operations no formal protective or surveillance measures which were specifically addressed to ionising radiation. In this respect, of course, practices in Australia before 1975 were no different from those in North America and Europe (with the possible exception of France). Uranium-mining and -milling operations conducted in Australia since 1975 have been regulated by codes of practice. The current code will apply to all projected uranium mines in Australia. Whatever the technical shortcomings of the codes,

140. See the legislation cited at n.93: S.A.: s.21; N.T · s.9; W.A.: s.7(1) (12 months: power to extend conferred by s.7(2)); and Limitation of Actions Act 1974-1981 (Qld.) s.31.

141. Watt v. Rama supra n.115.

142. See the legislation cited in nn.135, 136: S.A.: s.45; N.T.: s.36; Qld.: s.29; W.A.: s.40. Contrast the result in Morgan v. United States 143 F.Supp.580 (1956).

they have the substantial merit of being objective, published guidelines, open to public debate and capable of enforcement by workers and their representatives. The effectiveness of the current code is a matter for assessment by health scientists rather than by lawyers; suffice it to say here the current code appears to embody reasonable safeguards, internationally accepted protective standards and strict health surveillance mechanisms.

However, the standards set by the current code of practice (which are, after all, the result of successive downward revisions of exposure limits first set in 1954 and which are regarded as too high by some members of the medical profession, both in Australia and abroad) may not prevent injuries from ionising radiation. In addition, the health surveillance and monitoring mechanisms may somehow fail. In those events, the compensatory aspect of society's responsibility becomes important. Society's response to the problems of compensation posed by latent injuries due to ionising radiation may be radical or it may be confined merely to modifying existing schemes.

The present statutory schemes of workers' compensation appear to be barely capable of coping with latent industrial diseases, if one overlooks the sweeping objection that the quantum of compensation recoverable under these schemes is inadequate. A number of minor improvements might be made to the legislation. For example, the Act in Queensland should be amended so as to conform with the legislation in South Australia, the Northern Territory and Western Australia, where the burden of proof on the issue of causation is, in this context, cast on the employer or insurer.[143] The statutory formula "pathological manifestations due to radioactive substances" (which is connected with the provision reversing the burden of proof) should be made more explicit. In addition, the limitation periods in the legislation should be amended so as to cater explicitly for latent diseases; alternatively, the latency of a disease should be deemed to be "reasonable cause" for late lodgement of a claim.[144] Copies of records of exposures and of medical examinations required to be made and retained under the code of practice should be required to be transmitted to the government department administering the workers' compensation legislation in the relevant state, and should be admissible in evidence in proceedings for the recovery of compensation, in exception to the hearsay rule, if they are not admissible under existing legislation.[145]

As far as the common law regime of compensation is concerned, reforms

143. See the text at n.81 above.
144. See the text at nn.86, 87 above.
145. Such records would probably be admissible in South Australia pursuant to Evidence Act 1929-1981 s.45a.

could be merely cosmetic[146] or wholesale. The two areas in which reforms are most badly needed are in the areas of proof of causation and of securing the continued availability of a defendant. As has been stated already, injuries (including cancers) of putatively radiogenic origin cannot, in the present state of science, be proved to be connected with ionising radiation whether in a mine or elsewhere. Unless and until knowledge advances, plaintiffs in common law actions arising out of injuries (somatic or genetic) suspected to have resulted from ionising radiation will not be able to establish a causal nexus between radiation exposure in the workplace and the injuries complained of; and since the burden of proof of causation rests on the plaintiff in all relevant common law actions, common law remedies are unavailable to this class of claimant. Thus the statutory workers' compensation schemes become the exclusive remedy in this context. For this reason, any reform of the common law bases of recovery of damage which left untouched the problem of proof of causation of radiogenic diseases would simply be inadequate.

There appear to be two alternative approaches to solving this problem. On the one hand, the burden of proof in cases of radiation injuries could be reversed as between employee (or derivative claimant) and employer where the employee had been shown to have sustained a prescribed minimum exposure to radiation in the workplace. On the other hand, a compensation fund could be created out of which compensation would be payable to workers (or to dependents or descendants of workers) who presented with radiogenic injuries after the worker had sustained the prescribed minimum of exposure. In its essential details, the fund would operate as a monopolistic workers' compensation insurer (like the SGIO in Queensland). Its liability would be absolute. The issue of causation in particular cases would be dealt with by the application of irrebuttable presumptions created *a priori*, either by legislation or by administrative order. Provision should be made for claims on the fund under established common law heads of recovery (such as pain and suffering) which are not compensable under the workers' compensation legislation, by workers and by those with derivative claims. Models for such a fund already exist at the international level, namely the nuclear damage civil liability

146. E.g. the Limitation Act (W.A.) could be amended to confer on the court a power to extend the time within which actions for damages for latent diseases may be brought, to conform with the law in the other three jurisdictions discussed in this paper, the "once and for all" rule could be displaced by provision for the interlocutory assessment of liability and for the periodic determination, review and variation of compensation (cf. Supreme Court Act 1935-1975 (S.A.) s.30b); where, under the present scheme of things, an action for compensation against an employer would fail because the damage complained of is equally attributable to a second employment (i.e. where successive employers are several tortfeasors), provision could be made authorising full recovery against one employer and conferring on that employer a right of contribution from the other involved employers (cf. the workers' compensation provisions cited at n.83).

conventions and the oil pollution civil liability conventions.[147] Given the latency periods of lung cancer and the very nature of genetic injury, the limitation period applicable to the fund would have to be at least 30 years from the date of the last exposure (with a proviso barring claims, say, two years from the day on which the claimant has actual knowledge of all material facts entitling him to claim). In exchange for the guarantees of compensation provided by such a fund, it would be reasonable to impose limits on the amounts recoverable by individual claimants, as has been done in the international civil liability conventions alluded to. Given that almost all uranium mined in Australia is destined for export, the most equitable manner in which the fund might be financed would be by way of an export levy on yellowcake.[148]

A second advantage to workers inherent in the creation of such a fund, over and above that of dispensing with proof of causation, is that compensation would still be recoverable even after an employer corporation has been wound up or struck off the register of corporations. This is particularly important in the mining context where single-venture companies are frequently used. Concededly, though, this advantage could equally well be secured by controls over the general employer's liability insurance arrangements entered into by the mine and mill operators, to ensure the survival of a source of compensation, coupled with a legislative provision conferring on the injured worker a cause of action directly against the insurer of the claimant's past employer.[149]

If reforms of the nature indicated are not implemented, the adverse financial consequences of injuries due to exposure to ionising radiation in the workplace will be met, in the first instance, by the injured members of the workforce and their dependents and, secondly, by the general body of taxpayers in the form of higher expenditure on social security allowances, medical and hospital treatment subventions and so forth. What emerges from a perusal of the literature, legal and technical, dealing with the health risks of uranium mining and milling is an aura of uncertainty. The extent of the risks undertaken by workers cannot be assessed or measured with certainty. The adequacy of preventive measures can be known only long after the event. The extent to which current

147. See P. McNamara, *The Availability of Civil Remedies to Protect Persons and Property from Transfrontier Pollution Injury* (1981) 122-140; Nuclear Installations Act 1965 c.57(U.K.); Stason, Estep and Pierce supra n.4 at 516-527.

148. The net result of this class of taxation would be to pass the cost of the fund to consumers. The *Ham Report* concluded that the "costs of nuclear power for public use are so vast that the costs of being publicly responsible to uranium miners and their families are by comparison negligible": supra n.3 at 110. See also S. Peters, "Occupational Carcinogens and Statutes of Limitation" (1979) 10 *Env.L* 113, 152, where a justification is advanced for passing the burden of industrial cigarette-smoking, radiation exposure and lung cancer it would be logical to complement the proposed export levy with a proportion of the funds paid into Consolidated Revenue by way of tobacco taxes.

149. Cf. Law Reform (Miscellaneous Provisions) Act 1956 (N.T) Part VIII.

Australian safeguards are practicable, workable and effective is still being discovered in the workplace.[150] Equally uncertain is the extent to which the law can and will cope with the peculiar problems of latent radiogenic diseases. These sundry areas of uncertainty redound to the disadvantage of the workforce. As one health practitioner has observed, their removal is not a technical, scientific or legal matter, but a political matter, to be achieved in the quasi-political forum of the industrial arena:

> From a scientific point of view, we now know that no safe standards can be set. The only safe standard is no exposure. From a pragmatic point of view, it may be better to set standards than to do nothing. But the question is: on the basis of which criteria will you set these standards? The only way you can do it is by making risk-benefit analysis. The workers run the risk but have no benefit. Consequently, setting standards is not a *scientific* problem, but a political one, because the only scientific threshold limit value is zero. It is of great importance that workers who are exposed to carcinogens and suspected carcinogens understand this, and that nobody tries falsely to make it a scientific problem.[151]

150. "By the proper application of the Codes of practice and the co-operation of all concerned, it should be possible to obtain the best information possible in radiation exposure of individuals. When this is used in conjunction with medical surveillance of individuals over their working life-time and later years, it should be possible to determine if the radiation protection standards incorporated in the Codes . are suitable": Swindon supra n.42 at 213

151 H. Larsen in I.L.O. supra n.33 at 536.