APPENDICES

Effects of Atomic Radiation on Man and his Environment

(Extracts from the *Report of the United Nations Scientific Committee on the Effects of Atomic Radiation*)

CHAPTER III (vi)—"*Environmental Contamination*"

38. Radioactive contamination of man's environment occurs as a result of nuclear explosions and may also arise from radioactive waste disposal and accidents involving dispersion of radioactivity. At the present time, the radiation doses from these last two sources are negligible, but in the future they might become appreciable.

Radioactive fall-out

39. Most of the radioactive isotopes which cause the environmental contamination following nuclear weapon tests are fission products. There are also some formed by neutron induction and some residual fissionable material.

Fall-out mechanisms

40. Fission products injected into the stratosphere constitute a reservoir from which they fall on to the whole of the earth's surface over a period of many years (stratospheric fall-out). Fission products not penetrating into the stratosphere may be transported over long distances in the troposphere by air currents but are deposited on the earth's surface by rainfall and sedimentation over a priod of a few months (tropospheric fall-out). Because of the gradual deposition of fall-out from the stratosphere, most of the resulting irradiation of man arises from radioactive isotopes of long half-life such as strontium-90 and caesium-137. In contrast, the earlier deposition of tropospheric fall-out makes it necessary also to consider the doses from radioisotopes of much shorter half-life such as strontium-89, zirconium-95 and ruthenium-103 and 106, iodine-131, barium-140, and cerium-144.

41. Near the test site there is an early deposition of radioisotopes which is influenced by various meteorological and testing conditions and which may involve a special hazard to any individual in this area of immediate local fall-out.

42. Meteorological conditions and the predominant occurrence of nuclear tests in the northern hemisphere cause a non-uniform deposition of the longer-lived isotopes over the globe, as a result of which countries between 30° and 50° North experience a deposition of these about three times as great as the world-wide average. Countries in the southern hemisphere and in the tropical belt have smaller deposits with a maximum between 30° and 50° South, of the order of the world-wide average value D18. In some countries, tropospheric fall-out increases the deposition of the longer lived isotopes strontium-90 by a small amount. Local meteorological and climatic factors influence the extent and mode of the deposition in a particular locality.

Measured contamination of air and ground by strontium-90 and caesium-137

43. Results of measurements of strontium-90 and caesium-137 concentrations in different materials show an average air concentration at ground level of strontium-90 of the order of 10^{-19} to 10^{-17} c/l in 1956-1957 D-10/11. Values for strontium-90 deposited on the ground at the middle of 1957 were about 8mc/km² in Japan, 8mc/km² in the United Kingdom, 4-21mc/km² in the United States and 3-12mc-km² in the Soviet Union, in the northern hemisphere, and about 4mc/km² in Argentina, in the southern hemisphere. At the middle of 1957 a caesium-137 deposit about 6mc/km² was measured in Japan and Sweden.

Uptake of radioisotopes

44. Radioisotopes enter the human body by inhalation of airborne material and more particularly by ingestion following (a) uptake by and deposition on vegetation, (b) transfer through animals, (c) contamination of water supplies. In this respect strontium-90, caesium-137 and iodine-131 are of special importance. The particulate nature of fall-out and the occurrence of single particles with an activity higher than the average might result in the intake, by a single individual, of an amount of radioactive material exceeding that calculated on the assumption of uniform distribution of the fall-out deposit. The relative importance of the various modes of intake must, however, be considered in assessing the significance of this.

CHAPTER V (iv)—"*Summary and Conclusions*"

62. A large body of knowledge has accumulated during the last sixty years on the somatic effects of ionizing radiations on man and animals. This knowledge has come from numerous observations on human beings and from extensive experimentation with laboratory animals. In both cases, the effects of external and internal radiation have been studied and, although many of these effects are far from being understood in all details, our knowledge is sufficient to provide a general picture of the events that occur after human beings and animals have been exposed to ionizing radiations of all kinds. In general, the effects following exposure to relatively large doses are well known, whereas the effects of small doses are not understood nearly as well.

63. All types of ionizing radiations produce similar biological effects; these are usually not distinguishable from other pathological conditions. Some radiations, such as neutrons and alpha rays, are more efficient in producing certain types of somatic effects. Physical factors of exposure such as dose, dose rates and dose distribution are as important in determining the nature and extent of the biological effects as are the age and sex of the individual exposed and the part of the body that has suffered exposure. Radioactive isotopes produce harmful effects in those organs in which they are selectively retained. The extent of these effects depends on the physical characteristics of the isotopes, such as on the half-life, and the type and energy of the radiations emitted as well as the time of retention in a particular organ and the sensitivity of that particular organ to radiation injury. Absorption of measurable quantities of radioactive materials in human beings and animals has been demonstrated in recent years. Strontium-90, having a half-life of 28 years and being deposited selectively in bone, may be cited as an example to which particular attention must be given.

64. Exposure to relatively large doses of external or internal irradiation produces a variety of characteristic and well-known somatic effects which may occur either immediately or with a delay of a few days to several years. Certain organs, such as the blood-forming organs, the skin and the gonads, are particularly vulnerable to injury by ionizing radiations. Many of the actue effects, such as erythema of the skin and radiation sickness follow-

ing whole body exposure have characteristic threshold doses. Similar thresholds exist for acute blood and bone disorders following ingestion of large amounts of radium and other radioactive materials.

65. The tissues of the embryo and foetus are among the most sensitive to radiation. Malformations and other pathological conditions have been observed following exposure of pregnant women to accidental and therapeutic irradiation and to diagnostic procedures, e.g. pelvimetry. Experimental work has demonstrated that radioactive materials, such as strontium and other soluble radionuclides circulating in the blood of the mother, can be absorbed and deposited in foetal organs, such as the skeleton, where they may produce lesions.

66. As the dose of radiation is reduced below the amounts giving rise to acute functional or morphological alterations, the reactions of the organism become more difficult to detect immediately and the effects may be progressively delayed in time. Thresholds are not easily revealed under these conditions of exposure, in fact, for some of the most delayed phenomena, it is uncertain whether they exist.

67. It is a very characteristic feature of radiation injury that delayed reactions may occur many months or years following exposure. The morphological and functional alterations which occur during the long periods of latency are poorly understood. It has been shown that even after such periods acute manifestations of somatic effects may develop. Among the late effects, leukaemia, bone cancer and other malignant changes are worthy of mention. It has been demonstrated that whole-body exposure can shorten the average life span of experimental animals, and it is possible that the same may be true for man.

68. Small doses of radiation given repeatedly can have a cumulative effect in those cases in which the processes of recovery and compensation are limited. It is not known whether sensitization occurs. The existence of adaptation in the broad biological sense of the term has not been proved.

CHAPTER VI—"*Conclusions*"

35. It is accepted that radiation-induced mutations are, in general, harmful and increase in direct proportion to the genetically significant exposure, even at very low dose levels; and that a dose of between 10 and 100 rads per generation would probably be required to double the natural mutation rate in human populations. About 4 per cent of all births are affected with hereditary disorders, some one-quarter of which appear to be at least largely determined by single gene differences. On this basis, an increase in the mutation rate would eventually result in a directly proportional increase in a part of this 4 per cent amounting to more than one quarter but less than the whole of it. In addition, there would be some changes in other hereditary characteristics of a less sharply defined nature, but the probable extent of these and their importance cannot be assessed at the present time. The Committee concludes from the foregoing genetic facts that exposures to ionizing radiation should be reduced wherever possible, and that medical and industrial procedures tending to increase radiation levels to which human populations might be exposed should be carefully weighed as to such benefits or hazards as each may have.

CHAPTER VII—"*Summary and Conclusions*"

1. In estimating the possible hazards of ionizing radiation, it is clearly necessary to know both the levels of such radiation received by man and his environment from various sources, and the present and future effects likely to be produced thereby. It is of particular importance to assess the effects of radioactive fall-out from nuclear weapons, since this source of general environmental contamination is of recent origin, and has led to concern in the minds of many people. All sources of radiation must, however, be reviewed for a complete evaluation of the situation.

2. The Committee, aware of the complexity of this task, knows that our present information about radiation levels and effects is inadequate for an accurate evaluation of all hazards, and that many of the estimates will necessarily be approximate or tentative.

Radiation from fall-out

16. Fall-out from nuclear weapon tests causes radiation exposure in several ways. Exposure of the world population results

from the slow fall-out of fission products which have been distributed in the stratosphere. Exposures also result from any fall-out from the radioactive "cloud" which passes through the troposphere without having reached the higher stratosphere, and from the fall-out which may occur in areas adjacent to weapon tests or within some thousand kilometres of them.

17. We also consider the ways in which fall-out material causes irradiation to different parts of the body, to people on different diets or under different agricultural conditions, and to people of different ages; and the change in the amounts of radiation that would result from altered or unaltered rates of injection of radioactive materials into the stratosphere.

Fall-out adjacent to tests

18. The early fall-out of radioactive materials near to the sites of nuclear explosions, which is influenced by various meteorological and testing conditions, may cause high radiation exposure to individuals within these areas. The amount of such radiation exposures varies very greatly with the weapon tested, with the height of firing, with the distance from the point of explosion, with the direction of winds at various altitudes and with the chance occurrence of rainfall through radioactive material in the early hours after the test. Therefore, at present, these doses cannot in general be calculated. Under very special conditions, high radiation exposure and deleterious effects have been reported, as in the cases of the Marshall Islanders and the crew of a Japanese fishing vessel. Not enough information is available as to the general circumstances in which such local deposition may occur, and the extent and duration of the exposures liable to be involved.

Fall-out from the troposphere

19. Radioactive materials injected into the atomsphere below the tropopause (at about 14 km) are brought down to the earth's surface by rainfall and sedimentation. This process takes a few months during which they are carried several times around the world. This tropospheric fall-out consists of a mixture of radioactive materials, most of which are short-lived isotopes. At the present time, the tropospheric fall-out is deposited intermittently, during the year and a certain deposit of short-lived activities is built up and maintained. When appropriate factors for shielding and

weathering effects are included, the gonad and average marrow dose from this deposit, as an external source, is calculated to be about 0.5 mrem per year.

20. Transient increases of the doses from tropospheric fall-out have been observed in limited areas shortly after weapon tests. These transient increases may give rise for a few days to dose rates of the order of those from natural sources.

21. The radioisotopes of tropospheric fall-out may be taken up into the body by inhalation and ingestion. Since the radioisotopes of principal concern are short-lived, storage of the contaminated food products reduces the dose which they contribute. The gonad dose over the whole population from inhaled and ingested tropospheric material is negligible as compared with the contribution from this material as an external source. The average bone marrow dose from internal sources is about 0.2 mrem per year.

22. Increases in radioactivity of the thyroid gland have been found during periods of several weeks or a few months following weapon tests. In human thyroids a dose from iodine-131 of about 5 mrem per year has been estimated for 1955-56 in the United States excluding areas immediately adjacent to weapon test sites. Doses of this order are unlikely to cause detectable damage or functional change in the gland.

23. Irradiation of bone may result from incorporation of intermediate and short-lived fission products. Although these materials do not cause prolonged irradiation, they may become selectively concentrated into those areas of bone in which active growth is taking place at the time, and so cause more intense radiation locally than if the same amounts of these materials were distributed throughout the whole skeleton.

24. The Committee has insufficient information on local variations and temporary increases of tropospheric fall-out in populated areas at different distances from weapon test sites, and emphasizes the lack of further data which would permit evaluation of the biological significance of this source of environmental contamination.

World-wide fall-out from the stratosphere

25. Radioactive materals injected into the stratosphere, especially by high-yield nuclear explosions, constitute a reservoir from which they fall on to the whole of the earth's surface for many years. The rate of fall-out varies with latitude and is greater in the northern hemisphere, where most of the tests are carried out. Within any given small area, fall-out rate may also vary with local meteorological conditions. The radiation due to stratospheric fall-out from weapons exploded so far will contribute a 30-year gonad dose of 10 mrem, and a 70-year *per capita* mean marrow dose of 160 mrem and 960 mrem for two populations deriving most of their dietary calcium from milk and rice respectively.

26. Owing to the relatively gradual fall-out from the stratosphere, most of the subsequent radiation is due to two radioactive isotopes of slow decay, other fission products already having largely undergone decay. These two radioactive isotopes are caesium-137 and strontium-90. The physical properties and chemical behaviour of the two differ.

27. Caesium-137 is responsible for most of the gonad radiation from fall-out. When it is taken into the body, it becomes distributed more or less evenly throughout the tissues, causing uniform irradiation of the whole body; and when present in the surroundings, its penetrating gamma radiations cause a similarly uniform irradiation of tissues.

28. Strontium-90, on the other hand, is not a gamma-emitter and does not contribute significantly to the irradiation of any part of the body from without. However, on being taken into the body, it becomes incorporated in bone because of its chemical similarity to the normal bone-forming element calcium. This similarity with calcium and selective concentration in bone raises problems which do not occur with caesium-137.

29. The average concentration of strontium-90 in the bones of children, in whom new bone is continuously being formed, is higher than in adults whose bones were largely formed before the environment, and consequently the food supply became contaminated with strontium-90. The highest concentrations of strontium-90 in bone have in fact been observed in children from a few months

to five years old. The bone marrow exposures from fall-out are due to the strontium-90 content of bone and refer to the concentrations estimated for children of these ages. The corresponding exposures of bone cells from fall-out are, on the average, about three times the values for bone marrow. Marrow cells almost enclosed by bone would receive doses similar to those in compact bone. The maximum marrow dose could differ by a factor of about 5 from the average level.

30. The radiostrontium concentration in bone is also affected by dietery habit and by the ratio of the amounts of strontium-90 to calcium in the diet. At present this ratio differs in various dietary constituents; it is higher in brown rice than in white, somewhat higher in many vegetables than in milk products, higher in rain-water than in river water, and lower in sea fish than in fresh water fish.

31. Agricultural conditions may also affect the content of strontium-90 in the diet, since the available calcium of the soil will, within certain limits, influence the ratio of strontium-90 to calcium in crops derived from the soil. The distribution of soils which are highly deficient in calcium and their utilization require further study. More work is also needed to understand the distribution of strontium-90 in the soil, its chemical availability in plants and uptake through their roots, its behaviour under ploughing and the leaching of it from soil by the action of water.

Since the figures in table I for future strontium-90 levels in bone are calculated on the assumption that this material will not be leached from soil, and this assumption may lead to unduly high values.

32. Bone marrow exposures from fall-out are given in table I for two conditions : one based on observations in the United States of America and the United Kingdom, where milk is the main source both of dietary calcium and of strontium-90, and where soil calcium contents are commonly high; and the other based upon data from Japan where milk products are much less used and where rice and other vegetable products form the main source of dietary calcium and strontium-90, and where low calcium soils are frequent. These two estimates demonstrate the present range of known dietary contaminations. They will be used in an attempt to estimate the

hazard of radiation from fall-out in paragraph 57 below, when the nature and frequency of the biological effects of radiation have been considered.

33. It is evident that the radiation exposures from fall-out which are most likely to be of significance are :

(*a*) Those from short-lived fission products and radioactive material due to local or tropospheric fall-out;

(*b*) Those of the gonads and other organs from caesium-137 due to stratospheric fall-out ;

(*c*) Those of bone and adjacent tissue from strontium-90 which also comes largely from the stratosphere. The relative importance of these contributions varies from region to region.

Biological Effects of Radiation

34. The biological effects of ionizing radiation are exhibited in different ways according to whether isolated cells, tissues, organs or organisms are examined. In passing from unicelluiar to higher organisms, the primary physico-chemical consequences of radiation become increasingly influenced by secondary effects due to the reactions of the organisms to the primary events. Detailed knowledge of these reactions is needed for a full understanding of the results and mode of action of radiation. The following paragraphs deal first with the cellular effects of radiation; then with the somatic effects on the irradiated individual and with the genetic effects on his progeny.

35. The effects of ionizing radiations on living matter are extremely complicated, and their exact mechanisms are still largely unknown. The initial disturbance is associated with ionization (and excitation) of molecules which lead to alterations in their properties. Many functions of the cell are thus affected by radiation, and, although some specific effects may be caused by one or a few events in the cell, many are probably the combined result of numerous such events.

36. The minimum doses causing certain detectable biological effects differ very much in different organisms, but for most mammals they are of about the same magnitude, so that the results of experiments on such animals can, as a first approximation, be applied to man. The sensitivity of different tissues to radiation

varies considerably, however. Our knowledge of the biological effects of low radiation levels is meagre because of experimental difficulties and the lengthy observations necessary to obtain results in this field. At present, opinions as to the possible effects of low radiation levels must be based only on extrapolations from experience with high doses and dose rates.

Effects of radiations on man

37. Man may prove to be unusually vulnerable to ionizing radiations, including continuous exposure at low levels, on account of his known sensitivity to radiation and the end of the period of reproduction.

38. Embryonic cells are especially sensitive to radiation, and some evidence suggests that exposure of the foetus to small doses of radiation may result in leukaemia during childhood. Irradiation of pregnant mammals has shown that doses exceeding 25 rem to the foetus during certain stages of its development can cause abnormalities in some organs. Some embryonic cells (neuroblasts) of certain species cultivated *in vitro* respond to doses as small as 1 rad. If these results should be applicable to man and since they relate to the development of the brain, the opinion seems justified that even a very small dose to the human foetus may involve some risk of injurious effects if received during a critical period of pregnancy. Radiostrontium must be expected to enter foetal bone when calcification starts in the second trimester of pregnancy, and so cause irradiation of the adjacent developing nervous system and hypophysis with exposures ranging upto that occurring in the bone. The uptake of radiostrontium in foetal bone tissue is, however, at present very small, contributing less radiation than 1 per cent of that due to natural sources; but if the present rate of test explosions is continued, it will rise ultimately to some 10 per cent of that due to natural sources.

39. Children are regarded as being more sensitive to radiation than adults, although there is little direct evidence on this subject, except for an indication that cancer of the thyroid may result from doses of a few hundred *rad* which do not induce this change in adults.

40. In human adults it is difficult to detect the effect of a single exposure to less than 25 to 50 rem, or of continuing exposure

to levels below 100 times the natural levels. The first sign of radiation damage to the blood forming tissues seems to be a drop in the number of lymphocytes and platelets and the appearance of abnormalities such as bilobed lymphocytes.

41. Rapid but transient disturbances have been observed in mammals after exposure to a single dose of 25 to 200 mrem. Appropriate biochemical and physiological techniques have, however, only recently been applied to the study of irradiated organisms, and have not yet given a clear picture of what happens to organisms irradiated with small doses or dose rates. Too few mammalian species have hitherto been studied in this respect, and there is a clear need to widen this basis, from which inferences can be drawn concerning man.

42. Processes of repair play an important role in the final outcome of radiation damage. They are one cause of the existence of a threshold dose (or dose rate) characterized by the fact that this dose or greater ones produce a particular biological effect which does not appear when the dose is less than the threshold. In the latter case, physico-chemical events have occurred, but recovery processes have prevented the final appearance of biological damage. Threshold doses are found for some somatic effects, such as erythema of skin. Other forms of radiation damage to cells, tissues or organisms, however, appear to be cumulative; for instance, mutational damage, once established, is not repaired.

43. Damaged cells or tissues may be eliminated and replaced by regenerated normal cells, this process being most active in embryos and young animals and in certain tissues of the adult. The affected cells may also re-establish apparently normal biochemical functions. During the process of regeneration of tissues damaged by radiation, malignant tumours may be induced.

44. The power of repair differs considerably in different organisms and types of cells, and varies to a high degree with the physiological conditions. No chemical treatment has yet been discovered which will induce or accelerate recovery from radiation damage in man. The grafting of blood-forming tissue has so far been successful only in small mammal irradiated with a lethal dose to the whole body, and no attempt to apply this treatment to irradiated man has yet been reported.

45. Prevention of the effects of radiation is rendered more difficult, and complete protection against it impossible, because changes which already occur during the irradiation lead to later damage. The discovery of chemical protectors, although important theoretically, has not yet yielded methods which appreciably reduce radiation damage in man. At present, effective protection from external radiation sources can only be achieved by adequate shielding or by keeping at a safe distance from the source. Much work is in progress on the effect of certain (chelating) agents in discharging from the body radio-isotopes incorporated there, and so diminishing exposure to internal radiation.

46. Morphologically recognizable damage may be induced by total or partial, continuous or intermittent irradiations much in excess of the currently accepted "maximum permissible levels" of occupational exposure. Such damage includes leucopenia, anemia and leukeamia. Other pathological conditions such as cataract, carcinoma of the thyroid, and bone sarcoma are known to have resulted from partial body irradiations, but with rather high doses involving hundreds or even thousands of rem given to these organs.

47. The shortening of the life-span in small rodents exposed to large doses has suggested the possibility that certain degenerative processes may be aggravated by continued exposure to low radiation levels. Such a shortening has also been inferred from an analysis of the published death rates of United States radiologists compared with those of certain other groups of medical men. However, studies in the United Kingdom have failed to demonstrate such an effect.

48. Present uncertainty about the effects of low dose levels makes it imperative that as much relevant information as possible be collected about groups of persons chronically exposed at these levels and for whom adequate control groups exist, for instance, certain populations in areas of high natural radiation and workers in uranium mines.

49. Exposure of gonads to even the smallest doses of ionizing radiations can give rise to mutant genes which accumulate, and are transmissible to the progeny and are considered to be, in general, harmful to the human race. As the persons who will be affected,

will belong to future generations, it is important to minimize undue exposures of populations to such radiation and so to safeguard the well being of those who are still unborn.

50. The present assumption of the strictly cumulative effect of radiation in inducing mutations in man is based upon some theoretical considerations and a limited amount of experimental data obtained by exposure of experimental organisms to relatively high dose levels. This assumption underlies all present assessments of the mutational consequences of irradiation. Therefore, extension of the experimental data to the lowest practicable dose levels is needed.

51. The knowledge that man's actions can impair his genetic inheritance, and the cumulative effect of ionizing radiation in causing such impairment, clearly emphasize the responsibilities of the present generation, particularly in view of the social consequences laid on human populations by unfavourable genes.

52. Besides increasing the incidence of easily discernible disorders, many of them serious but each compratively rare, increased mutaticn may affect certain universal and important "biometrical" characters such as intelligence or life-span. In this way, it is possible that continued small genetically significant exposures of a population may affect, not only a correspondingly small number of individuals seriously, but also most of its members to a correspondingly small extent. While less easy to detect, this second kind of effect on a population could also be serious. Unfortunately, the great majority of the genes affecting the "biometrical" characters are not individually detectable and so can only be studied collectively and with difficulty. In consequence, far less is known about them than about genes responsible for individually detectable changes and very little indeed about their response to irradiation, even in the best studied experimental organisms. Hence it is impossible, at the present time, to estimate with any assurance the effect upon biometrical characters of any given level of irradiation of human populations. Much further research throughout this field is therefore needed.

APPENDIX II

Legal Problems in the Use of Radiation Sources

(Extracts from the *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Geneva*, 1955.)

PUBLIC LIABILITY

There has been considerable discussion, particularly among lawyers, concerning the matter of civil liability for radiation damage and much speculation concerning the liability rules which will apply in the event of an atomic accident. It is reasonable to assume that the utilisation of atomic energy will raise unique problems but it is difficult to conceive of any which cannot be resolved within the framework of existing legal systems. It is equally difficult to assume the answers, and the principles of legal responsibility which will prevail must await the facts and practicabilities of particular cases. There are, however, certain precedents in the law which by way of analogy indicate future issues which may arise.

Liability of owners and operators of facilities

An accident causing public damage will raise the issue of strict liability, or liability without fault, under which proof cf negligence is unnecessary. In 1866, the English Court of Exchequer first announced the doctrine that one "who for his own purposes brings on his lands and collects and keeps there anything likely to do mischief if it escapes, must keep it at his peril, and, it he does not do so, is *prima facie* answerable for all the damage which is the natural consequence of its escape."

In affirming, the House of Lords limited the use of the rule to situations involving a "non-natural" use of the land (*Rylands* v. *Fletcher*, L.R. 3 H.L. 330 (1868) affirming L. R. 1 Ex. 265 (1866). The doctrine is incorporated in the *American Restatement; of the Law of Torts*, which recognises the general rule that there is no liability for 'unintentional and non-negligent" conduct even where harm results, but announces a single class of exceptions for so-called "ultra-hazardous activities." Section 159 states that: "......one who carries on an ultra-hazardous activity is liable to another whose person, land or chattels the actor should recognise as likely to be harmed by the unpreventable miscarriage of the activity for harm resulting thereto from that which makes the activity ultra-hazardous, although the utmost care is exercised to prevent the harm."

This concept of strict liability has been applied to the storage of explosives, to blasting, and to ground damage from aviation. Its extension to damage from radiation caused by escaping fission products, in those countries which accept the doctrine, would seem to be consistent with the generalised rule of ultra-hazardous activities.

It is, however, far from clear that one could support a general statement that strict liability will be applied in all cases of atomic accidents. Much will depend on technological developments, on the availability of insurance permitting the risk to be spread, and on prevailing social values, particularly where the operation involved is for the benefit of the public generally and is essential to the good of the State as a community. There are, furthermore, certain legal defenses which might succeed—the fault of the plaintiff, intervention by a third-party, acts of God, normal or ordinary use of the land, and statutory authority. The latter two may well prevail in the typical fact situation which can be hypothesized. The English Courts themselves have excluded absolute liability where the activity in question was "merely......the ordinary use of the land or such a use as is proper for the general benefit of the community. (*Richards* v. *Lothian*, (1931) A. C., 263 (P.C.)] and it has been indicated that the manufacturer of explosives in wartime may be an "ordinary user" (see *Read* v. *Lyons*, (1945) K. B. 216, 240 (C. A. 1944). Legislative permission to conduct an activity has the same effect as "natural user." In *Northwestern Utilities Ltd., v. London Guarantee & Accident Co.*, 154 L. T. R. 89 (P.C. 1936), the rule of strict liability was held inapplicable to a utility company whose gas escaped into a basement and exploded, on the ground that the company located and used its pipes in accordance with statutory permission. *A fortiori* if, in addition to statutory authority, a defendant could show that his activities in all respects were conducted in accordance with official regulations and standards.

The presence of the State as a party in any litigation due to the ownership of the reactor fuel will raise additional questions relating

to (a) the scope of the State's liability—compare Section 2(1)(c) of the British Crown Proceedings Act (10 & 11 Geo 6, c. 44) which imposes governmental liability absolutely by reason of the ownership or control of an extra hazardous instrumentality with Section 410(a) of the United States Federal Tort Claims Act which apparently requires a "negligent or wrongful act or omission" of a government employee; and (b) liability for discretionary acts—see *Dalehite* v. *United States*, 346 U. S. 15 (1953), relieving the United States Government from liability in connection with the Texas City disaster by reason of the discretion and policy decisions involved in the Government's ammonium nitrate fertilizer programme.

If it should be required that proof of negligence is a condition to the imposition of liability, there is a further principle in tort law which will benefit a plaintiff and ease the problems of proof; namely, the principle of *res ipsa loquitur*. Basically, this doctrine, which applies when the cause of the injury or damage is under the sole control of a defendant and experience indicates that the accident causing the harm will not happen if due care is exercised, permits the drawing of inferences of negligence from a mere recitation of the occurrence. It has been applied in a variety of circumstances—an unexplained explosion in a power factory, boiler explosions, unexplained airplane accidents, bursting bottles, falling ceilings—and it is quite likely that an argument will be made for application in a case involving a reactor accident. The following language from an opinion of one of our state courts in boiler case indicates the approach which may be taken:

> "Boilers sometimes explode. Comparing the number of explosions with the extent of the use of boilers, explosions are not frequent. If they are kept in proper condition and repair, and if they are operated properly, explosions are unusual. Whether the *res ipsa* doctrine, which permits an inference of negligence from the fact of an explosion, should apply is largely a question of how justice in such cases is most practically and fairly administered. There is nothing illegally illogical in permitting the inference to be drawn. Usually the party injured is without information upon which he may with certainty allege the exact cause, and is without direct proof. Perhaps the exact cause is incapable of ascertainment. The actual proof, if any, is