Michigan Law Review

Volume 59 | Issue 2

1960

Radiation Injuries and Statistics: The Need for a New Approach to Injury Litigation

Samuel D. Estep
University of Michigan Law School

RADIATION INJURIES AND STATISTICS:

THE NEED FOR A NEW APPROACH TO INJURY LITIGATION†

*Samuel D. Estep**

In dedicating this effort to Dean Stason I wish to acknowledge that his pioneering foresight in this area where law and technology mix was responsible for my own interest and publications on atomic energy legal problems. I wish to give credit to Dean Stason for showing the way as well as giving much wise counsel in the course of our joint research publications. At the same time I must absolve him of any responsibility for whatever shortcomings this article and the idea here discussed may have. — S.D.E.

THE emphasis given by the mass media of communication to some of the dramatic problems arising from the use of nuclear energy unfortunately has diverted attention from some of the matters about which something can be done by lawyers, administrators, and legislators without the necessity of complicated international negotiations between various parties to the "Cold War." The headlines leave the uninformed, and perhaps often also the informed, public with the impression that even for radiation injuries the important problems all deal with such questions as: (1) Will only a few or many millions of people survive an all-out nuclear war? (2) Will the fallout from nuclear weapons testing cause no, a few, or hundreds of thousands of cases of leukemia and similar diseases among the populations of the world?

Leaving aside the difficulties connected with nuclear warfare and considering only those involved in peaceful uses of atomic energy, the attention of the general public and even of government officials usually is directed to such questions as these:

(1) Should nuclear reactors, whether on land or in ships, be permitted close to large population centers?

(2) What type of licensing, inspection, and operating procedures should be followed to protect the public and

† The ideas here presented were first discussed in a paper delivered at an International Symposium on Legal and Administrative Problems of Protection in the Peaceful Uses of Atomic Energy, sponsored by Euratom in Brussels, Belgium, in September 1960. The paper there delivered is being published by Euratom as a part of the proceedings of the Symposium.

I gratefully acknowledge the financial support for the research on which this article is based which was made possible by a grant from the Michigan Memorial Phoenix Project of the University of Michigan. I also wish to express my indebtedness to my research assistant, Martin Adelman, particularly for the mathematical calculations upon which the analysis and conclusions are based.

* Professor of Law, University of Michigan. — Ed.

workers who possibly may be exposed to harmful radiation and still permit reasonable development and use of nuclear energy?

(3) How high or low should the maximum permissible radiation exposure standards be for the public and nuclear workers?

These questions and many others unconnected with the problem of radiation injuries should not be minimized. Concentration of all of our attention and energy on these broad policy questions, however, is at the expense of developing the basic information and legal techniques for providing an adequate scheme of compensation for those who inevitably will be overexposed. An amazing safety record has been achieved by the nuclear industry so far and enough is known about radiation safety to support an argument that it is safer to handle radiation than many other types of material which industrialized countries have been using for decades. In any event, if care is used in exploiting this energy the benefits of such exploitation clearly outweigh the disadvantages. Moreover, it is inevitable that nuclear power will become an increasingly significant factor in our industrial development. With this expanded use, however, will come more accidents and an increase in exposure injuries.[1] Now is the time to face the problem of how to handle the radiation injury cases which will arise.

The attention which has been given to the matter of radiation injury by businessmen, union leaders, government officials, legislators, and even lawyers has centered on the relatively obvious questions of extending workmen's compensation coverage to include radiation injuries and providing insurance programs which will protect the nuclear industry from impossible potential liability burdens and also assure the public of an adequate fund for recourse in the event of a radiation accident. Most of this attention has been directed to the possibility of accidental exposure of large numbers of people in the unlikely but apparently not impossible event of release of large amounts of radioactive material in a large population center.[2] The damage and proof problem, however,

1 On September 2, 1959, the Atomic Energy Commission reported to the Joint Committee on Atomic Energy 26 separate unusual exposure incidents, all of which were additions to an earlier list reported by the AEC to the Committee in December 1958, *Hearings Before the Subcommittee on Research and Development of the Joint Committee on Atomic Energy on Employee Radiation Hazards and Workmen's Compensation*, 86th Cong., 1st Sess. 855-58 (1959). See also note 79 *infra*.

2 See, *e.g.*, Gomberg, Bassett & Velez, *Report on the Possible Effects on the Surrounding Population of an Assumed Release of Fission Products into the Atmosphere from 300-Megawatt Nuclear Reactor Located at Lagoona Beach, Michigan* (1957).

is equally important whether a small number of workers or other persons, or a large number of the general population, has been exposed.

Even the scientists who do nuclear research usually make the headlines only if they have developed some new idea for a more refined nuclear weapon or for a method of producing electrical power more cheaply or in a more usable production package for special situations than is possible with conventional fossil fuels. The scientists, however, for some years have recognized a need for basic research in the biological effects of radiation on living organisms, particularly man, and are beginning to attract the necessary financial support. It is now time for the members of the legal profession, including those working in government, to provide the fundamental legal research which will make it possible for our legal system to use the knowledge which scientists over the years will develop concerning the effect of radiation on man. The type of scientific information already available and that which at present seems to be on the horizon calls for a new legal approach.

The most important legal problem in dealing with radiation injuries concerns the matter of damages and proof. (1) What types of injuries shall be compensable? (2) How can biological causation be proved? (3) If compensation is to be allowed, how should it be computed and dispensed? Until the legal profession, working with legislators and government officials, has answered these basic questions, our society is not ready to assimilate fully the technology being developed by the nuclear scientists.

The three questions posed are fundamental because they must be answered under *any* legal system which is to allow recovery for radiation injury *regardless* of how other legal issues are framed and resolved. Whether there is a jury trial, trial by judge, or an administrative board determination; whether the question arises under workmen's compensation or normal tort liability concepts; whether it is permissible to split a cause of action, as we find in some of the French cases, at least with regard to the damage question, or whether an Anglo-American type of legal rule is followed which requires that a cause of action for all possible damages be brought at one time; whether large recoveries are permitted with no limitations or some limitations are imposed; whether determination of the amount of the award is made by jury, an administrative agency, or statute; and whether the rule of liability is one based on fault or on strict liability, deciding what injuries to compensate, proving biological causation, and administering the compensation awarded are the three common and basic questions. Numerous other difficult questions are discussed elsewhere.[3] For some types of typical radiation injuries, the existing concepts are incapable of providing such answers.

Of the many types of injuries which may result from irradiation of human beings, the greatest difficulties will be presented by those which as yet can be related scientifically to radiation only by an increased incidence among an exposed population. When the onset of the disease or injury is latent (delayed), predictions of future incidence are based on statistical possibilities. When, in addition, the biological causal relationship also is non-specific (it may be caused by radiation but also arises among *un*exposed groups and *no differentiation* between those cases caused by radiation and those caused otherwise is possible), the legal problems, difficult before, become unmanageable under existing rules.

The American authorities relevant to a determination of compensability for the injuries here discussed are collected elsewhere,[4] so this discussion will emphasize the last two of the basic questions, biological causation and administration of compensation. Nevertheless, a very brief summary of conclusions concerning compensability will indicate more sharply the need for new solutions for the other two problems.

I. COMPENSABLE DAMAGES

Short statute of limitations periods will prove an obstacle to recovery for some radiation injuries in most jurisdictions, but nearly everybody concerned recognizes the need for extending such periods for radiation exposure cases. Surely one is entitled to assume such changes will be made. In any event, recovery for these kinds of injuries should not be denied merely because they are not manifested for more than two or three years after exposure. A more difficult question is that of causation.

Some radiation injuries obviously are compensable now under both workmen's compensation and tort principles. If causation is proved, such things as cataracts and skin burns of a crippling nature, to mention only two, clearly would be compensable. On the

3 STASON, ESTEP, & PIERCE, ATOMS AND THE LAW (1959), of which the present writer was principal author (hereinafter referred to as ATOMS AND THE LAW). *E.g.*, effect of statutory or administrative rulings (p. 114); care owed to licensees and others (p. 130); vicarious liability (p. 163); multiple defendants and cumulative effects of radiation (p. 361); application of res ipsa loquitur (p. 533); the federal indemnity program (p. 572); strict or fault liability (p. 635); and product liability (p. 725).

4 *Id.* at 199-308.

other hand, certain possibilities, such as mental disturbance and pre-natal injuries, have been held uncompensable by some courts when other forces are the causal factor because courts feared the proof problem was too difficult and the door would be opened too wide for possibly fraudulent claims. Such courts also might be inclined to deny recovery for some radiation injuries because of the serious proof difficulties which give rise not so much to a danger of fraudulent claims but to an inability to make causation specific.

Injuries should not be excluded from the compensable group merely because proof of causation under existing rules is uncertain. In some cases causation undoubtedly will be fairly clear and recovery should be allowed. In addition, in a fast-developing field such as this, what cannot be proved with today's scientific knowledge may be capable of proof tomorrow. In those cases in which the proof of causation is made difficult under existing rules because of the statistical character of radiation effects, a new system of handling such cases must be adopted. The basic policy question of whether or not to allow a certain kind of injury to be included within the compensable category should be made on the basis of whether or not this is the kind of claim for which the legal system desires to provide recovery. This basic question should be answered first without regard to the difficulties of proof. If no scheme can now be devised to handle the proof problem, recovery should be denied only until scientific advances make it possible.

Of the many radiation injuries which undoubtedly will arise under both workmen's compensation and ordinary tort liability concepts, the following most clearly require some new legal approaches.

A. *Increased Susceptibility to Disease*

Scientists generally agree today that exposure to significant amounts of radiation increases a person's general susceptibility to diseases to which he may thereafter be exposed. In some types of situations this may be a problem quite similar to that of job disability. A person working in a pharmaceutical laboratory may find it unsafe to continue in such an occupation after serious overexposure to radiation because the research or production work is being done in an atmosphere creating a greater than normal chance for exposure to disease. The same might be true of a doctor, nurse, or other person who treats the diseased. It is impossible to prove that a particular person so exposed would in the future contract a given disease, whether it is the common cold or pneumonia. So long as the person does continue to work and contracts no disease there is no decreased earning capacity. Therefore, perhaps even under normal tort liability rules, and certainly under typical workmen's compensation concepts of decreased earning capacity, no recovery would be permitted. Nevertheless, in some situations it might be very desirable for the irradiated person to find another occupation, and an appropriate award should be allowed.

The over-all policy question remains of whether to award some kind of compensation under either or both workmen's compensation and tort liability rules simply for the increased susceptibility to possible future disease. Since increased susceptibility is most dangerous in old age, this problem is most likely to arise with regard to retired persons not covered by workmen's compensation provisions. Existing American cases do not make it clear whether this injury is compensable on a tort basis.[5]

B. *Shortened Life Span or Premature Aging*

Scientists accept the conclusion that irradiation shortens the life expectancy of the victim, although they do not agree as to how much. Different countries reach different results, but this should not be a compensable injury except to compensate those deprived of financial support by the accelerated demise of the exposed person, or in other special circumstances.[6]

C. *Sterility and Related Injuries*

Irradiation can impair the ability to have children, and, perhaps most importantly, greatly increases the chance of deformed offspring. Conflicting lines of authority exist in the United States[7] but the loss of the ability to have children should not be a compensable item of damages, not because proof will be difficult but because the loss is one for which money in no way can compensate.[8] The emotional loss of parents when a living child is lost probably also should go uncompensated, although the increased expense of caring for a deformed child should be recoverable, of course.

5 *Id.* at 257-270.
6 *Id.* at 270-309.
7 *Id.* at 242-54.
8 *Id.* at 254-56.

D. *Genetic Damage*

The injury to unborn generations caused by irradiation of any potential parent, at least above very low, possibly threshold levels (and there may be no threshold), is probably the most disturbing of all possible radiation injuries. Any increases in the normal mutation rate almost always result in latent, non-specific deformities or death in descendants because most mutations are harmful to man. In sufficient quantities, of course, radiation-induced mutations in the whole population could upset the present genetic mutation equilibrium. But even for an individual exposed to high levels of radiation, such as 300 or more units (as has happened in the United States),[9] the resultant much higher risk of a genetic deformity in an offspring may be a real tragedy manifested in the form of a cleft palate, club foot, cross-eyes, mental deficiency, or any one of perhaps hundreds of identifiable deformities.[10] As with sterility and shortened life span, the irradiated person has suffered no decreased earning capacity and hence has suffered no compensable injury under most workmen's compensation statutes. Likewise, in ordinary tort claim situations, no Anglo-American authority was found permitting recovery.[11]

Providing for such injuries for even five, let alone ten or twenty generations, probably is beyond the capacity of existing legal systems. Provisions should be made, however, for at least those in the next generation who have observable disabilities for which compensation would be granted under existing personal injury rules if the causal link were not genetic. To one who must bear such a deformity the rest of his life, it makes little difference whether it is the result of a genetic mutation or some somatic injury after conception or even after birth. Under existing rules, a very good case could be made to "prove" that a deformity in the child of a parent seriously overexposed just before conception, and hence well within the statute of limitations period, was "caused" by the radiation. The result reached under existing rules

9 Andrews, Sitterson, Kretchmar, & Brucer, *Accidental Radiation Excursion at the Oak Ridge Y-12 Plant-IV,* 2 HEALTH PHYSICS 134 (1959).

10 Reported to the First International Congress on Congenital Malformations, held in London in July 1960. Report by N. Y. Times, July 19, 1960, p. 5, col. 6.

11 ATOMS AND THE LAW 225-27. The only case at all close was Morgan v. United States, 143 F. Supp. 580 (D. N.J. 1956), where it was alleged that a faulty blood transfusion was given to a woman who gave birth to a sickly child two years later. This jurisdiction, however, denied all pre-natal injuries at that time and therefore no precedent for preconception injuries was made.

in such cases is unrealistic, whether recovery is denied or permitted, because of the statistical character of "causation," and something in the nature of the contingent injury fund discussed below should be used. Nevertheless, if rules remain the same, deformed persons whose parents were exposed to so-called doubling doses of radiation[12] should be allowed to recover regardless of the fact that the causal link is genetic.[13]

Many have avoided even discussing the problem of genetic damage for fear that people will be frightened away from considering some of the other problems admittedly important to the development of a nuclear industry.[14] The issue should be faced now, however, and a decision made as to what injuries to compensate and under what circumstances.

E. *Leukemia and Other Cancers*

If existing limitations periods for bringing causes of action after injurious impact are extended, as they should be, legal cases involving latent cancers, such as leukemia, will result from irradiation and problems will be created which are incapable of fair solution under existing workmen's compensation or tort liability rules. Scientists do not agree as to the causal connection between irradiation and some cancers. This is true of strontium-90 and bone cancer,[15] and also of iodine-131 and cancer of the thyroid.[16] The relationship between long-delayed leukemia and overexposure to at least high level radiation, however, is undisputed.[17] The painful, disabling and, eventually, fatal effects of leukemia are well recognized and the case for compensation seems obvious. Unfortunately, such injuries are not only long delayed but also in particular cases the causal connection with radiation is difficult to show with sufficient legal or scientific certainty to be acceptable under existing rules. In the first place, the connection can be measured

12 To be legally significant this should be considered to be that dose which will double the number of manifested deformities in a given generation, not just double the number of gene mutations in a given generation.

13 ATOMS AND THE LAW 227-34 and 498-501.

14 See UNIVERSITY OF MICHIGAN, WORKSHOPS ON LEGAL PROBLEMS OF ATOMIC ENERGY 37 (1956).

15 *Hearings Before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy on the Nature of Radioactive Fallout and Its Effects on Man,* 85th Cong., 1st Sess., 1666-68 (1957).

16 *Hearings Before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy on Fallout from Nuclear Weapons Tests,* 86th Cong., 1st Sess. 1552 (1959).

17 *Id.* at 1445-50.

only by a statistical increase in the incidence of the disease. Allowing damages relatively soon after exposure for any future possibility of occurrence of leukemia is a gamble unacceptable for an enlightened legal system. If suit should be delayed until the disease manifests itself, causal relationship to radiation is still impossible to prove with any degree of certainty *for the specific case.* This results from the fact that such diseases are non-specific as to cause; no differentiation can be made between radiation-caused leukemia and leukemia arising from those other forces which account for the natural incidence of this disease. These difficulties also indicate the need for a new legal treatment[18] along the lines of the contingent injury fund discussed below.

Even if the causation difficulty is solved, some possible obstacles to recovery remain. Definitions in workmen's compensation statutes of such terms as "occupational disease," "accident," and "arising out of and in the course of employment," and some of the reporting and other administrative details in such laws may prove troublesome, but these have been generally recognized and some changes in existing laws have been made and others are contemplated. On the other hand, little or no attention has been given to the fact that recovery may be denied because there will be no decreased earning capacity for a relatively long period of time after exposure, and then, in the case of chronic leukemia, real disability lasts perhaps only two months before death. An acute leukemia victim, however, will be disabled several months between onslaught and death if untreated, but still less than a year even if treated.[19] In either the chronic or acute leukemia case onslaught may occur after retirement and thus no decreased earning capacity is experienced. Although the treatment of chronic cases typically is not too expensive and can be handled on an out-patient basis, treatment for acute cases includes hospitalization and can be catastrophically expensive. Surely such expenses should be recoverable and the necessary modifications in existing statutes should be made.

Another damage policy question is presented by leukemia and similar cancerous diseases. There is some evidence that at least in many cases the only effect of radiation is to accelerate onslaught of a condition that would have arisen in any event.[20] Often even in

[18] Discussion beginning at p. 281 *infra*.

[19] Interview with specialists at the University of Michigan Medical Center.

[20] Heyssel and others, *Leukemia in Hiroshima Atomic Bomb Survivors*, 15 BLOOD 313, 223-24 (1960).

the additional cases "caused" by radiation, particularly in chronic cases with very short disability periods, the most significant effect is shortened life span and perhaps such cases should be handled primarily as involving only this type of injury. In any event, the policy decision of whether to allow recovery for such an injury, and if so to what extent and for whom, should be answered consciously and with full recognition of all ramifications. Such decisions should not be left for case-by-case development by individual judges. The basic decision as to damages should be made by statute in each jurisdiction.

Conclusion as to Damages

These questions of policy as to types of damages to be compensated are basic regardless of differences existing between jurisdictions and between legal systems. This is so whether strict liability or fault principles are imposed and whether the case is a tort liability or a workmen's compensation situation. Whether or not there is agreement with the conclusions suggested above, surely it can be agreed that it is essential that such policy decisions be made consciously and not left for decision by individual judges, administrators or juries on a case-by-case basis, so that uniform results, at least within a particular jurisdiction, can be reached. Such policy questions in unprecedented numbers will be presented in radiation cases and the law should be prepared to meet them intelligently and fairly. In doing so it may be necessary to re-evaluate some of the present concepts of compensable injuries in tort cases such as awards for pain and suffering, loss of enjoyment, support of dependents, and of survival of causes of action and awards for wrongful death and the interrelationship of the two.[21] Under any legal system, and regardless of other questions and their solutions, answers must be given on the questions here emphasized. Solutions should be agreed on before radiation cases begin to occur in considerable numbers. Failure to face these questions will itself be an answer but an unsatisfactory one.

II. PROOF OF CAUSATION FOR LATENT, NON-SPECIFIC INJURIES

Difficult as is the determination of which injuries ought to be compensable, and the amount of damages which should be allowed

21 ATOMS AND THE LAW 228-32, 299-308.

to the injured person, proving biological "cause-in-fact" for latent, non-specific injuries creates much greater problems under existing legal rules. Because radiation only increases the incidence of such injuries in an exposed group, is only one cause of many, and no way exists to distinguish those cases caused by radiation from those resulting from other forces, results reached in radiation cases under normal proof rules could best be described as a lottery. The chances of justice being done are dependent upon the laws of chance and have no relationship to the particular case before the court or tribunal. Proving cause-in-fact of course involves proving that plaintiff was exposed by some radiation source for which defendant is legally responsible and also proving the amount of such exposure. Such facts may be difficult to prove and mistakes may be made but there is nothing inherently or theoretically wrong with the conclusions drawn. Trying to prove for legal purposes the biological connection of irradiation with a particular non-specific, latent injury under existing rules, however, makes the "correct" result theoretically impossible. A new approach such as a contingent injury fund should be used.

Leukemia

First, the results which would be reached under existing rules for a particular disease, leukemia, will be analyzed to show how completely unsatisfactory this solution is for both future possibility and present manifestation of the disease cases. Then the theory and application of the contingent injury fund generally to non-specific injury will be described, followed by the application of the fund idea to leukemia. Finally, some of the litigation difficulties necessarily involved in handling many radiation cases under both existing and contingent injury fund concepts will be enumerated and some possibilities suggested for at least ameliorating some of them. Before making any of these analyses, however, the basic scientific "facts" of leukemia must be presented.

A. *Scientific "Facts" of Leukemia*

Under either existing rules or the contingent injury concept, legal analysis of radiation injury cases must begin with an understanding of the present state of scientific knowledge about the relationship between leukemia and radiation. The extensive scientific literature on leukemia[22] seems to justify use of the following generalizations for legal purposes.

1. Radiation, at least in doses of 50 to 100 units or more, causes leukemia in the sense that it will increase beyond the natural incidence rate the number of cases of leukemia in an exposed group. Radiation does not merely trigger or accelerate leukemia in a person who already was destined to have it, although it also may do this. This has been shown by the studies done on the populations of Hiroshima and Nagasaki,[23] on ankylosing spondylytics in England,[24] and probably by the reports on leukemia among radiologists[25] and among children exposed while embryos as a result of radiation treatment of their mothers.[26]

2. Radiation is a non-specific cause of leukemia. Other forces than radiation cause it and no method exists, or seems likely to be discovered in the near future, for differentiating between a radiation "caused" case and one arising as a matter of natural incidence from other causes. In addition, as yet no way exists for determining which members of any given group of the population, even one exposed to radiation, will contract the disease and which ones will not.

3. The normal or natural incidence of the disease varies from country to country and in accordance with sex, age, possibly heredity, and even occupation. In the United States the over-all leukemia rate is about 6.9 cases per 100,000 people per year,[27] or to use a scientist's shorthand form of expression, $6.9/10^5/\text{yr}$. This figure compares with one of $5.8/10^5/\text{yr}$. in 1950[28] and the increase

22 The scientific literature is rather extensive but the 75 or so significant articles on leukemia are cited in two papers: Heyssel, *supra* note 20, and Heyssel, *The Risk of Leukemia in Man Following Radiation Exposure, Proceedings of the Vanderbilt University Medical School Symposium on Radioactivity in Man,* held in April 1960, and yet to be *published. See also 1959 Hearings, supra* note 16, and *Hearings Before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy on Biological and Environmental Effects of Nuclear War,* 86th Cong., 1st Sess. (1959), which include references to most of the literature, and summaries or excerpts from many of the important scientific papers not only concerning leukemia but also concerning other radiation injuries. It is from these sources, as well as from interviews with various scientists and medical specialists that the scientific conclusions stated in this paper are drawn.

23 Hollingsworth, *Delayed Radiation Effects in Survivors of the Atomic Bombings,* 263 NEW ENG. J. MED. 481 (1960).

24 Court-Brown & Doll, *Leukemia and Aplastic Anemia in Patients Irradiated for Ankylosing Spondylitis,* MEDICAL RESEARCH COUNCIL SPECIAL REPORT SERIES, No. 295 (1957).

25 March, *Leukemia in Radiologists in a 20 Year Period,* 220 AM. J. M. SC. 282 (1950).

26 Stewart, Webb, & Hewitt, *A Survey of Childhood Malignancies,* 1 BRIT. MED. J. 1495 (1958), reprinted in *1959 Hearings, supra* note 16, at 1667.

27 National Office of Vital Statistics, 2 VITAL STATISTICS OF THE UNITED STATES 97 (1958).

28 National Office of Vital Statistics, 49 VITAL STATISTICS—SPECIAL REPORTS 341 (1958-1959) (hereinafter cited as VITAL STATISTICS—SPECIAL REPORTS). This figure is an average figure for the three-year period, 1949-1951.

is consistent with the experience throughout the world in recent years.[29] Most scientists feel this increase is not the result of better diagnosis but have no firm convictions as to the reason for the increase. This increase, coupled with the fact that the natural incidence rate seems too high to be attributable solely to background radiation such as from cosmic rays, clearly suggests that other forces than radiation cause the disease.

4. Between 30 and 80 units of radiation will double the natural incidence figure in an exposed group. At least the estimates of most scientists fall between these figures. The best *guess* for legal purposes would seem to be 50 units.[30] This number is known technically as the doubling dose and has great legal significance under existing proof rules. It is not known yet whether or not the doubling dose depends upon the dose being acute (received in one or a very few fractional doses) or chronic[31] (received in small doses over an extended period of time).

5. Scientists do not agree on the relationship between the amount of radiation received and the increased incidence of leukemia, usually referred to as the dose-rate curve. Although not absolutely conclusive, considerable evidence exists that for exposures of 50 to 100 units and above, the curve is linear.[32] This is a shorthand way of stating that any given increase in the number of units of radiation exposure will result in a corresponding and constant increase in the incidence of leukemia. In any event, at these levels of exposure, the curve approximates a linear curve sufficiently closely to permit use of this assumption in solving legal problems. Some have attempted to extrapolate from the incidence figures at these exposure levels an estimate of the number of cases of leukemia that will be caused per unit of radiation, such as two cases per year per million people exposed to one unit (expressed as $2/\text{rad}/10^6/\text{yr.}$).[33] Two difficulties inherent in this assumption have caused considerable skepticism in the scientific

29 Heyssel, *supra* note 20, at 314.

30 The amount of radiation exposure which constitutes a doubling dose is somewhat uncertain. The most accurate data comes from Court-Brown & Doll, *supra* note 24, at 50. They indicate that their data is consistent with a doubling dose in the range of 30-50 units. Conclusions drawn from analysis of all studies on individuals subject to X-rays are consistent with an estimate that 50 units doubles the chance of development of leukemia. *1957 Hearings, supra* note 15, at 1132.

31 *1957 Hearings, supra* note 15, at 1557.

32 Heyssel, *supra* note 20, at 327.

33 Lewis, *Leukemia in Ionizing Radiation,* 125 SCIENCE 965 (1957), reprinted in *1957 Hearings, supra* note 15, at 970.

community about such an extrapolation.[34] In the first place, even assuming linearity at the higher levels of exposure, there is no evidence that at lower levels the same incidence ratio will hold true,[35] and it may well be less. There is no suggestion it will be higher. In addition, many argue that a threshold level exists[36] which means that below this low level no additional cases will arise from such exposure, particularly if received in chronic doses. Others, of course, argue that it is linear, at all dose levels,[37] at least within the extremes of lethal doses (hundreds of units in one acute dose) and very low levels such as the maximum permissible levels permitted for radiation workers. For the foreseeable future, the law may have to frame rules for injury cases in spite of these uncertainties because studies of effects of radiation on millions of animals would be required to settle the questions presented at low dosages.[38] Possibly the uncertainty will not be settled until the scientists discover the primary biological mechanisms of leukemia.[39] If these are discovered the shape of the curve even at low doses probably can be determined from theoretical calculations without epidemiological studies of large numbers of exposed mammals.

6. The natural incidence figures are derived from death certificate reports for the whole population and all types of leukemia typically have been lumped together.[40] Today it is recognized that the different forms of the disease actually may be different diseases with different causal mechanisms.[41] There is some evidence that radiation, at least in acute, fairly large doses, does not cause one type of leukemia, *i.e.*, chronic lymphocytic.[42] The desirability of distinguishing the forms of leukemia is also indicated by the evidence concerning variation in incidence of the types in the different age groups.[43]

34 Brues, *Critique of the Linear Theory of Carcinogenesis*, 128 SCIENCE 693 (1957), reprinted in *1959 Hearings, supra* note 16, at 1402.

35 Heyssel, *supra* note 20, at 320.

36 Finkel, *Mice, Men and Fallout*, 128 SCIENCE 637, 641 (1958), reprinted in *1959 Hearings, supra* note 16, at 2346.

37 Lewis, *supra* note 33.

38 Buck, *Population Size Required for Investigating Threshold Dose in Radiation Induced Leukemia*, 129 SCIENCE 1357 (1959).

39 Letter from Robert M. Heyssel to Samuel D. Estep, April 22, 1960.

40 See note 28 *supra*.

41 Baikie, and others, *Chromosome Studies in Human Leukemia*, 2 LANCET 425, & 427 (1959).

42 Court-Brown & Doll, *Adult Leukemia*, 1 BRIT. MED. J. 1063 (1959).

43 *Id.* at 1064.

7. Radiation-induced leukemia apparently does not appear for at least one year and probably two years after exposure.[44] Some cases will not appear for at least thirteen to fifteen years after exposure and perhaps as late as twenty years.[45] The peak incidence occurs between the fourth and eighth years following exposure.[46] Thereafter the incidence among the exposed population diminishes and begins to approach the expected natural incidence rate.

B. *Application of Existing Cause-in-Fact Rules to Leukemia*

Leukemia was chosen first to test both existing damage and proof rules and the contingent injury fund idea for several reasons. In the first place, leukemia, as indicated before, is a latent, non-specific injury. In addition, more and better scientific information exists about both the natural incidence figure and the correlation between radiation and increases in the leukemia rate than for any other such latent, non-specific disease. We also have more knowledge of such correlations and rates as applied to human beings than with other diseases. The same basic problem will be presented by other such injuries, of course, and, although these will be the subject of future papers, this one deals with leukemia.

The common denominator which applies to all such injuries is the statistical probability character of the evidence which will have to be used in litigating such cases. This type of proof creates real problems for the existing litigation system and an analysis of the application of present rules to leukemia cases will demonstrate the "lottery" character of the justice derived from use of traditional concepts. A study of leukemia also will illuminate the problems involved in constructing an intelligent compensation system for these radiation injuries generally. The statistical character of the proof even offers the possibility of creating a fairer and perhaps ultimately simpler compensation scheme. Probably similar concepts will be applicable to many non-radiation injury cases, but that is another story.

44 Heyssel, *supra* note 20, at 329.
45 *Ibid.*
46 *Ibid.*

1. *Existing Rules of Proof*

The approach of the American courts in solving the problem of proving biological causation in injury cases has been analyzed previously.[47] A fair conclusion from this analysis is that the burden is on the plaintiff to show that "more probably than not" the force put in motion by the defendant caused the plaintiff's injury. A few courts use the term "reasonably certain,"[48] but most American courts use "reasonably probable." Although courts have not used the following terminology, a more realistic description could be framed in terms of percentages, and probably this is what juries at least subconsciously use in any event. The more-probable-than-not test surely means simply that the trier of fact must find that the chances that defendant's force caused the plaintiff's injuries are at least slightly better than 50 percent; or, to put it the other way, that the chances that all other forces or causes together could have caused the injury are at least no greater than just short of 50 percent. Even if such an analysis is inapplicable to other types of cases, in those cases in which the only proof of causal connection is a statistical correlation between radiation dose and injury, the only just approach is to use a percentage formula. This is the case with all nonspecific injuries, including leukemia. Under existing rules the only fair place to draw the line is at 50 percent. These rules apply when the injury is already manifested as of the time of trial. These cases involve what might be termed present injury situations.

The delayed onset or latency characteristic of leukemia creates a different and distinct problem. Although in a few jurisdictions in certain special situations courts have interpreted their statute of limitations as meaning that the cause of action does not accrue until the plaintiff knows he is injured and that the defendant's force caused it, in most jurisdictions the statutory period will begin to run immediately upon impact of the force, which in radiation cases will be at the time of exposure.[49] With existing limitations periods, most of which allow from one to three years for bringing the cause of action, nearly all leukemia cases resulting from irradiation will be barred by the statute unless it is permissible to sue now for the future injury.

[47] ATOMS AND THE LAW 421-94.

[48] *Id.* at 429 n. 926.

[49] See generally Annot., 11 A.L.R. 2d 277 (1950). See also Hutton, *Statutes of Limitations and Radiation Injury*, 23 TENN. L. REV. 278 (1954).

Many American courts have made a distinction in these future injury cases between the degree of probability required in two different situations. If a compensable injury is manifested at the time of trial and the only future uncertainty is the duration or degree of disability in the future, undoubtedly courts have generally been more liberal in allowing juries to grant speculative awards for such future disability, uncertain though the evidence of the future consequences is. On the other hand, if the only compensable injury is the possibility of future damages, the cases allowing recovery are practically non-existent and certainly the test used is likely to be "reasonable certainty," although occasionally courts have used "reasonably probable" and other somewhat less rigid proof tests. Even in such cases, however, it is clear that the degree of certainty required is considerably greater than that imposed under the "more probable than not" test used in present injury cases.[50]

No justification can be found for this kind of distinction, at least in radiation cases involving non-specific injuries. Except possibly for certain injuries such as skin burns resulting from gross overexposure to radiation where the causal connection is very specific, this is equally true of present injuries (manifested within the limitations period) because many of them may be non-specific as to causal connection. In many radiation cases the validity of the statistics as to biological causation is just as great for future consequences as it is for present injuries. Actually, the distinction between "reasonably certain," "reasonably probable," and "more probable than not" will not be important if suit must be brought now for future injuries, because none of these tests, even the most liberal one, can be met in most if any leukemia cases, and most leukemia cases will involve future possibility of injury only.

2. *Application to Leukemia Cases*

a. *Future Injury Leukemia Cases.* If the cause of action must be brought within a short period after exposure, no recovery in any case for the future possibility of leukemia would be allowed under any of the suggested tests. This can be demonstrated conclusively by use of the statistics showing the natural incidence of the disease. Using 1950 census figures,[51] no exposed person could

[50] ATOMS AND THE LAW 487-94.

[51] This figure was chosen because a detailed breakdown of the incidence of leukemia for the three-year period, 1949-1951, is available; see note 28 *supra*.

show that his chances were greater than 50 percent, let alone "reasonably certain." Of 100,000 exposed persons chosen at random from the 1950 United States population, 143 persons would die of leukemia from natural causes in the next twenty years, if no account is taken of those who will die of other causes.[52] By a

[52] A rough figure can be calculated for the number of leukemias that will appear normally in a random sample of 100,000 people followed for a 20-year period. The figure does not include the incidence from the first two years for these years do not yield compensable leukemias (note 44 *supra*). The U. S. Office of Vital Statistics has tabulated the incidence of leukemia for the three-year period, 1949-1951 (note 28 *supra*). Their figures are broken down into various age ranges, *i.e.*, 5-14, 15-24, etc. Normal mortality figures from all causes for the same time period and age groups are also given. The death rate figure is used instead of the incidence rate figure in the calculation. This introduces only a slight error because the usual course of leukemia is less than a year for acute cases and one to three years for chronic cases (note 19 *supra*). The figure is based upon a random sample of 100,000 people at age levels proportionate to those of the 1950 census. For each five-year group the age picked to represent the group was the lower age plus two: *e.g.*, age 27 was used for the 25-29 group. A formula was used to take into account the would-be cases of leukemia lost through death from other causes.

The total leukemia cases occurring during Y years =

$$ZN\left(\frac{1-(1\text{-}X)^y}{X}-2+X\right) \qquad \text{where } N = \text{no. in sample},\ Z = \text{rate of leukemia},\ X = \text{rate of total deaths}$$

The formula is derived by observing that ZN = the number of leukemias occurring during the first year; Z (N-XN) = ZN (1-X) = the number of leukemias occurring during the second year; and ZN (1-X) (1-X) = ZN $(1\text{-}X)^2$ = the number of leukemias occurring during the third year. Therefore, for Y years the total observed leukemias will total

$$ZN\left(1+(1\text{-}X)+(1\text{-}X)^2+(1\text{-}X)^3\ldots\ldots(1\text{-}X)^{y-1}\right) = ZN\sum_{\sigma=0}^{y-1}(1\text{-}X)^\sigma$$

Using the formula for the sum of a geometric series that

$$\sum_{\sigma=0}^{r} a^\sigma = \frac{1\text{-}a^{r+1}}{1\text{-}a} \qquad \text{let } a = (1\text{-}X),\ r = y\text{-}1$$

Hence

$$\sum_{\sigma=0}^{y-1}(1\text{-}X)^\sigma = \frac{1-(1\text{-}X)^y}{1-(1\text{-}X)} = \frac{1-(1\text{-}X)^y}{X}$$

Correcting for the first two years by subtracting the value Y = 2 one must subtract

$$ZN\left(\frac{1-(1\text{-}X)^2}{X}\right) = ZN\,\frac{1-1+2X-X^2}{X} = ZN\,(2\text{-}X)$$

Therefore, the formula for the total leukemias which will appear during Y years becomes

$$ZN\left(\frac{1-(1\text{-}X)^y}{X}-2+X\right)$$

The formula is used for the first calculation until Z and X change. Then N becomes $N(1\text{-}X)^y = N_1$ and the calculation continues using the new values of X and Z, but since there need be no correction for the first two years the formula simplifies to become

$$ZN_1 \sum_{\sigma=0}^{y-1} (1-X)^{\sigma} = ZN_1 \left(\frac{1-(1-X)^{y}}{X} \right)$$

This process is then repeated a third time in order to calculate the total incidence of leukemia in each age group over the twenty-year span. The results of this calculation are set out below.

Age	Natural Incidence	Number in Group	% of Population in This Age Group
0-5	4.8	10,700	10.7%
5-9	3.8	8,800	8.8%
10-14	2.7	7,400	7.4%
15-19	2.7	7,000	7.0%
20-24	3.4	7,600	7.6%
25-29	4.6	8,100	8.1%
30-34	5.6	7,700	7.7%
35-39	7.3	7,500	7.5%
40-44	8.9	6,800	6.8%
45-49	10.0	6,000	6.0%
50-54	12.2	5,500	5.5%
55-59	12.7	4,800	4.8%
60-64	11.3	4,000	4.0%
65-69	8.9	3,300	3.3%
70-74	5.3	2,300	2.3%
75-79	2.4	1,400	1.4%
80-84	.8	750	.75%
over 85	——	350	.35%
	Total 107.4		

The total number of cases caused by the radiation includes some that do not materialize because of death from another cause. This figure can be calculated by ignoring the normal death rate in the calculation. In other words, the assumption is made that the sample does not vary from year to year. This is not quite correct for the cases of leukemia that arise should be eliminated from the sample by using the leukemia death rate in place of the normal death rate in the formula. This would eliminate the possibility that any one person would be figured as having leukemia more than once. Since there is no cure, one can have leukemia only once. However, the correction is very small and an accurate picture can be obtained without this correction.

Age	A Priori Cases	% of Population
0-5	4.8	10.7%
5-9	3.8	8.8%
10-14	2.8	7.4%
15-19	2.9	7.0%
20-24	3.7	7.6%
25-29	4.7	8.1%
30-34	5.9	7.7%
35-39	7.7	7.5%
40-44	9.7	6.8%
45-49	12.0	6.0%
50-54	15.1	5.5%
55-59	16.3	4.8%
60-64	17.0	4.0%
65-69	15.4	3.3%
70-74	11.1	2.3%
75-79	6.6	1.4%
80-84	3.3	.75%
over 85	——	
	Total 142.8	

relatively simple mathematical calculation which nevertheless seems complicated to most lawyers, one can determine that of these 143 potential cases, only 107 will die of leukemia because the other 36 will die of other causes.[53] Twenty years is taken because twenty years is assumed to be the latency period for leukemia resulting from irradiation, and to determine recoverability under existing rules, it is necessary to compare the natural incidence cases with those which would be caused in the same 100,000 group by a doubling dose of radiation.

Using 107 as the natural incidence figure, and assuming a doubling dose is received by an "average" person of the 100,000, the present chances of his getting leukemia will be 214 out of 100,000, or roughly .2 of 1 percent.[54] This is a far cry from even a 50 percent chance. Assuming unrealistically that a person could survive an acute exposure of 1000 units, almost certainly a lethal dose, and taking 50 units as the doubling dose for adults, a person so exposed still has only a 2 percent chance of getting leukemia in the next twenty years.[55] Taking the lowest possible leukemia doubling dose situation, which is 2 to 5 units for a human embryo, recovery for future possibilities would still be denied in every case. Using the 1950 census figures, the normal incidence of leukemia among persons under twenty years of age is found to be $2.5/10^5/\text{yr}$.[56] Taking 200 units as a dose almost certainly lethal to an embryo, and using the lowest doubling dose figure, 2 units, the most heavily exposed surviving embryo would have only a 5 percent chance of contracting leukemia in the next twenty years.[57]

Therefore, the conclusion is irresistible that under existing rules there is no chance whatever for recovering at the time of irradiation for any future cases of leukemia. Yet the best scientific estimate is that doses in the range of 50 units for adults, perhaps even less for young persons, and still less for embryos, will cause as many cases of leukemia among exposed persons as can be expected to occur as a result of natural causes. If 100,000 were exposed this would be 107; if 10,000 were irradiated, 10.7; and if 1,000, one case. Because of the short limitations periods and the

53 Note 52 *supra*.

54 214/100,000 = .00214 = .214%.

55 20 x 107/100,000 = .0214 = 2.14%.

56 This is a rough figure estimated from the VITAL STATISTICS—SPECIAL REPORTS. An accurate figure is not possible since the incidence varies with age.

57 100 x 2.5 x 20/100,000 = .05 = 5%.

common law rule against splitting of causes of action, most leukemia victims will be denied recovery in the United States.

b. *Present Injury Leukemia Cases.* Equally unjust results, although in the opposite direction, will be reached under existing rules if suit is permitted after leukemia actually occurs in the exposed person. In a very few cases this could arise under existing American limitations rules. More importantly, because nearly everyone who has thought about the problem agrees that the statutory periods must be extended substantially for such radiation injuries, the number of these suits should increase greatly. This type of unfairness will occur under any system which permits delayed determination of damages, including the French system where under certain circumstances one may wait and see what the future injuries are.[58]

In such situations, *any* person who has been exposed to slightly more than a doubling dose (picking 50 units for adults and 5 for embryos) can recover. Every exposed person, including those whose leukemia results from natural causes rather than defendant's radiation source, can "prove" that "more probably than not" defendant's source "caused" his particular case. If the exposure has been slightly less than a doubling dose, of course none could recover. If 100,000 persons receive slightly more than a doubling dose, 214 will get leukemia over the next twenty years and all can hold the defendants legally liable under existing rules, although defendants "caused" only 107 of the cases.

This wait-and-see approach solves the latency problem but in no way adequately handles the non-specific causal connection question. Waiting until onslaught of the disease before suing in no way makes more certain the proof of correlation between radiation and leukemia. Proof still is purely statistical in nature; the chances have been increased but assignment of natural and radiation causation to specific cases is impossible.

The wait-and-see doctrine does have the advantage, of course, of denying recovery to those who do not later get the disease. But defendants will be forced to pay for twice as many cases as they caused if a doubling dose is received by plaintiffs and many plaintiffs whose chances are less than 50 percent will be denied recovery unjustifiably if slightly less than a doubling dose has been received.

58 ATOMS AND THE LAW 527-32.

c. *Translation into Dollar Values.* If a monetary value is placed on leukemia the injustice of the above results will be more obvious. Whether the monetary figure is determined by a schedule such as under workmen's compensation acts, or is set by juries in normal tort liability situations, the unfairness is the same. Arbitrarily selecting $20,000 as the average award for leukemia (admittedly this could be $1,000, $50,000, or even $100,000), and using 107 as the natural incidence number, a figure of $2,140,000 is reached. If 100,000 persons were exposed to a doubling dose of radiation and suit must be brought immediately after the exposure for the possibility of future injuries, 107 people will be denied $2,140,000 in damages they legitimately claim they will suffer. On the other hand, if a wait-and-see doctrine is used, defendants will pay not only the $2,140,000 properly charged to them but an additional $2,140,000 for the 107 cases caused not by their radiation but by natural causes. This is $107,000 per year of unjustifiable charges.

Nothing in the doctrines of strict liability or liability-only-for-fault justifies either result. Nor does the possibility of scaling down each plaintiff's recovery for future injuries by the percentage of risk represented by the natural incidence figure really solve the problem. Two wrongs do not make a right, even if they average out in dollar figures over a number of cases. This is equally a gambler's system of justice because there is no correlation of recovery with specific cases. Compensation will be granted to some unnecessarily and full recovery unjustly denied to others. A roulette wheel is no better than a lottery.

The causation problem is a difficult one and in some cases not capable of a completely accurate or satisfactory solution. Nevertheless, this does not justify an attitude of judicial nihilism by accepting existing rules. Surely the law must not accept the role of administering a lottery. The unjust results reached under existing rules for both present and future injury suits calls for a new approach of administering recoveries for leukemia and other non-specific radiation injuries. If the contingent injury fund were used and sufficient cases were included to avoid random errors in using the statistical correlations, *theoretically* full compensation would be paid to those who get leukemia and no windfalls would be paid to those who do not, even though their chances of doing so were very great.

C. *The Contingent Injury Fund*

1. *General Theory of the Fund*

The basic theory of the contingent injury fund is simple and its application to such non-specific injuries as cancer and genetic damage has been suggested earlier,[59] although no attempt was made to consider the details and complications of creating and administering such a fund. Subsequent scientific findings give no greater hope than before of proving biological causation except by statistical correlations of the amount of radiation with incidence of the disease in an exposed population. Some recent evidence even indicates that perhaps the list of non-specific injuries which may be related statistically to irradiation will include multiple sclerosis and disturbed mental capacity, concentration, and even behavior.[59a] Therefore, it is time to test the feasibility of the contingent injury fund idea.

Under the fund concept, once the fact and amount of irradiation and the responsibility for it are determined, however this is done, all of the defendants who irradiate others would contribute in proportion to the *increased chances* of some latent disease created by the radiation exposure legally charged to them. If the scientific determinations upon which the contributions were based are accurate, *and if a contribution has been made to cover the natural incidence cases,* the fund should be sufficient to permit compensation of each exposed person who actually contracts the disease later. Those who are exposed but do not get the disease would recover nothing and the contributions made for them would be used to compensate fully those who do. This permits the law to provide compensation only for those who are damaged and to make a fair charge to each defendant based on the increased risk caused by him. When liability and amount of contribution are determined and the defendant has paid, his liability is discharged. When the victim gets leukemia, for example, he would recover fully merely upon proof that he has the disease. Biological causation *for his specific case* would not have to be proved either at the initial determination of the fact of exposure and value of the injury should it occur, or at the time of onslaught of the disease. The biological causation would be determined statistically and the charges to the defendants and payments to

[59] *Id.* at 513-22.

[59a] *Radiation Threat to the Brain?* Bus. Week, Sept. 17, 1960, p. 83.

the plaintiffs would be established on the basis of the biological statistical correlation. Only the natural incidence cases are unprovided for and several solutions to this problem are available.

This statistically-determined contingent injury fund could be handled in at least two different ways. A government-administered fund could be created and the contributions of defendants would then be collected and distributed by the government agency in charge of the fund. All of the difficulties of a government bureaucracy could be avoided if the insurance industry would make available insurance policies which pay a person a given amount if he contracts some disease such as leukemia. The insurance premium would be determined on the basis of the same scientific statistical correlation figures and would be paid by the defendants in accordance with the increased risk of the disease caused by each defendant's radiation source. If the insurance industry will undertake this task this is preferable, but if the industry feels the risks are too great, then a government-administered contingent injury fund should be created.

Many difficulties will have to be resolved in creating and administering the fund idea but they are no more difficult than those inherent in our existing rules governing personal injury cases. More importantly, the contingent injury scheme would come much closer to actual justice in individual radiation injury cases. It would be based on a wait-and-see doctrine with full payments to those who do succumb to the disease and no windfalls to those who are exposed but do not contract it. It would be equally applicable in all legal systems, common law or civil, and in tort liability or workmen's compensation situations. It could be used regardless of what method is utilized for determining liability or of finding facts in litigation situations because it is based on a universal scientific phenomenon, biological cause-in-fact.

a. *Providing for the Natural Incidence Cases.* The most important difficulty connected with use of the contingent injury fund concept is providing sufficient funds to permit payment of *all* victims of non-specific diseases among the exposed population. This number will include the natural incidence cases along with those additional ones caused by radiation, but no defendant will have made a contribution to cover these natural incidence cases. No distinction can be made between these and the radiation-caused cases so that all victims must be compensated from the fund in order to permit proper recovery for those for which the radiation is responsible.

The several possibilities suggested here for handling the natural incidence difficulty can be understood best when applied to a particular non-specific disease, such as leukemia, as set out below. Nevertheless, this problem is so essential to a proper application of the contingent fund idea that the possibilities should be stated in general terms first. They all are equally applicable to each of the non-specific radiation-caused injuries, once the natural incidence number is determined.

One factor which at least ameliorates the problem is to take account of those victims among the exposed population who ordinarily would be expected to contract the disease but who before the disease manifests itself die of other causes in no way attributable to irradiation. Other causes include accidental deaths from car collisions, drowning, electrocution, etc., as well as non-radiation related diseases. The figures, at least for leukemia, indicate that this makes a very significant reduction in the natural incidence figure. This number of potential victims will not seek recovery from the fund, and no contribution need be made for them. The natural incidence figure in certain cases can be further reduced if the population exposed is a select group not made up of a random sample of the general population. Likewise, in determining the figure, at least for leukemia, it is possible that some types of the disease are not caused by exposure to radiation and therefore persons with this form of the disease should not recover from the fund. In spite of these reductions, however, a significant number of natural incidence cases must be covered. Several solutions are possible.

One possibility is to make all defendants insurers against all non-specific, possibly radiation-caused diseases later contracted by all persons for whose exposure defendants are legally responsible. This not only could result in a possibly extremely serious financial burden but also seems basically unjust in a system aimed at providing compensation for victims, not punishing those who unintentionally *may* have injured others. This is not like the thin-skull cases, nor is it really analogous to the substantial-contributions-to-causal-chain situations and should not be handled by imposing liability on defendants for cases they have not caused.

A related possibility is to tax the whole atomic energy industry (not just one or a few defendants who are responsible for irradiating others) to provide sufficient funds to permit recoveries for the natural incidence cases which cannot be distinguished from the radiation-caused ones. This is unjust for the same reasons mentioned above and differs only in that it spreads the risk among more people. It is even more unjust in that it spreads the risk to many members of the industry who have not caused the exposure of others. In addition, an extremely difficult administrative problem would be involved in determining whom to include within the "nuclear industry," how much each member of the industry should contribute, and how long to continue the contributions if a member ceases to use radiation sources.

A third, and certainly less unjust possibility is simply to consider this as part of the price society has to pay for having nuclear technology. The contributions to the fund to cover the natural incidence cases would be made by the public at large out of general funds created by typical sources of government revenue, mostly taxes. No good reason suggests itself for treating in this special way diseases which happen to be caused also by radiation. The financial burden on society and on the individual victims, and the suffering by such persons, is no greater than with many other diseases to which man is subject and which are non-specific so far as cause is concerned.

A fourth possibility can be justified somewhat more easily under existing personal injury damage concepts, but, if one is constructing an ideal damage system, probably it should not be used either. In a few obvious cases when a sharply reduced life expectancy reduces the expected length of pain and suffering and medical expenses, the damage award is reduced because of the reduced expectancy. Probably in the majority of cases, however, such as broken bones and similar relatively short term injuries, awards are not reduced by the possibility that the victim will die prematurely the next day in an automobile accident, for example. If this concept were carried over into the radiation injury situation, one could argue that defendants should pay into the fund in accordance with the number of cases of a disease their radiation could be expected to cause without reduction for those who would die of other causes. Actually a substantial number, if a doubling dose exposure were received by the group, would die of other causes before onslaught of the disease and therefore would make no claims against the fund. The contributions for these cases could then be used to cover some of the natural incidence cases for which no contributions had been made. If a tripling or quadrupling dose were received by a large percentage of those who make claims against the fund, conceivably the entire natural incidence number would be taken care of. One difficulty is that until experience has been gained with accidental exposures one cannot know that the exposures will be at this high level and the fund must be financed before this experience can be gained. More importantly, a theoretical objection makes this solution unsatisfactory if emphasis is placed on compensation and not punishment in our personal injury liability schemes. In a real sense defendants have not caused such diseases in those persons who die of other causes before they contract the disease. The total injuries *for which money can compensate* actually is only the aggregate of the injuries suffered by those who get the disease, not those who might have, had they not died of other causes prematurely.

Another solution would be to scale down the amount any victim could recover from the fund by an amount equal to the percentage chance that his case was caused by natural, non-radiation-connected forces. One difficulty with this possibility is that it makes the plaintiff's recovery inadequate at the very time he needs it most, when the disease strikes. Actually, it has most of the disadvantages of the existing rules in that some of those who do contract the disease will be getting windfalls because their cases were not caused by radiation and others will be denied the full recovery they have a right to expect since their cases were caused by the radiation. Because no way exists of distinguishing radiation-caused from natural incidence cases of such diseases this is inevitable. The only advantage of such a solution is that it reduces the amount of claims made against the fund to the amount which defendants will have contributed, but it will not take care of victims fairly or adequately.

A modification of this use of the statistics of natural incidence and of the relationship between radiation and such non-specific diseases makes possible a much fairer solution of the natural incidence problem. In the absence of any exposure to radiation, the cost of the natural incidence of leukemia and similar diseases is borne by those who contract the disease. Because these diseases are not only non-specific but also latent, an insurance principle can be used to reach a just result. If all exposed persons who later will be allowed to recover from the fund for contracting the disease would be required to contribute to the fund a small sum to cover the natural incidence possibilities, then they would be paying for the natural incidence risk which ordinarily is theirs anyway and enough would be contributed to cover these claims against the fund. If all exposed persons contributed at the time of establishing their future rights against the fund, the contribution would be very modest and within the financial capacity of most any victim. Under this plan, defendants would pay for the number of cases their radiation would be expected to cause, plaintiffs would pay for the natural incidence risk which other than for the fortituous circumstance of irradiation would be theirs anyway, and full recovery could be permitted to each exposed person who does contract the disease.

Although the last solution seems the best, legislatures might adopt some other. In any event, it is important that some solution be found for the natural incidence cases because the contingent injury fund idea seems to hold the only possibility for a fair solution of the causation questions in radiation injury situations. No matter which solution for natural incidence is adopted, such a contingent injury scheme clearly permits results preferable to those which would be reached under existing rules as indicated below in the analysis of leukemia and proof of causation.

b. *Administrative Difficulties.* (1) *Broadness of coverage.* However the scheme is administered, by governments or insurance companies, a broad base must be used to minimize random statistical fluctuations. In the United States this means a base larger than one state, and undoubtedly the best plan would be to cover all radiation injuries throughout the entire country. In Europe it would be best to use as a base at least all of the countries participating in Euratom.

Another difficulty related to broadness of coverage is that of making sure that all plaintiffs and all defendants are included. Some way must be found to inform potential plaintiffs of any exposure and to encourage them to bring their causes of action as soon as possible after exposure. Because radiation is not perceived except by special instruments and below relatively massive doses causes no immediate effects, this may be difficult. Our traditional legal concepts relating to champerty and maintenance may have to be modified. Potential victims should be advised of their exposure (regardless of adoption of the contingent injury fund) even if there is reason to believe they otherwise would never know of the exposure.

Making it financially attractive for plaintiffs to bring their causes of action immediately is more difficult, primarily because at first such suits will not be very rewarding for plaintiffs' attorneys. In the first place, recoveries from the fund are to be delayed until the disease manifests itself, often many years later, yet most of the expenses of trial are incurred in determining the fact of exposure, the existence of liability, and the amount of damages. The chances of even delayed recovery from which the attorney could expect to recover his fee are not very great in an individual case. Most attorneys for exposed persons would go uncompensated. Even a doubling dose creates only 143 potential cases of leukemia, for example, out of 100,000 exposed persons, and 36 of these will die from other causes.[60] Even a quadrupling dose makes the chances of a particular individual recovering an award only 428 (107 times 3 plus 107 natural incidence cases) out of 100,000. The only feasible solution under present practices is to have radiation injury specialists who handle enough claims to make it very economical to try the plaintiffs' cases, and to have enough cases for each lawyer so that he will get a reasonable fee from such cases considered as a whole. Something must be done to encourage such specialists and to have multiple claims handled in one suit by one attorney. Here again concepts prohibiting the encouragement and payment of litigation expenses by lawyers, not to mention advertising, will have to be changed. Perhaps a bar group could establish a board of specialists from which potential victims are actually encouraged to select their counsel. This changes traditional and cherished concepts of practice and reduces the imagined freedom of choice by plaintiffs. Unless something is done along these lines, however, plaintiffs will not be well represented in most cases, or must gamble considerable money by way of trial expenses without a very great hope of eventual recovery.

(2) *Intervening exposures from other sources.* Account also must be taken of other intervening exposures between that for which the defendant is responsible and the occurrence of the disease. The plaintiff has no incentive to bring another cause of action against another defendant who has caused additional irradiation because plaintiff already is fully covered by an insurance policy or the contingent injury fund. Perhaps some kind of accurate records of people who have been exposed and who have made a claim against the fund will have to be kept to determine when they have been exposed again during the period before onslaught of the disease. It may be necessary to give the

60 Note 52 *supra.*

insurance company or the fund the right to bring such additional actions against new defendants. Such exposures as are caused by medical x-rays and radioisotopes should not give any great difficulty if the base is large enough because such exposures are included now in the natural incidence figures. Also, with increasing awareness of the dangers of radiation exposures, the medical profession is doing much to reduce use of radiation to a minimum consistent with the need for proper diagnosis and treatment.

2. *Application of Contingent Injury Fund Concept to Leukemia*

a. *Assumptions.* For purposes of illustrating the application of the contingent injury fund idea to leukemia certain assumptions have been made. These should be enumerated although they all are believed to be reasonable for legal purposes. The population group selected is 100,000 persons which as to age, sex, occupation, and heredity are a random sample of the population of the United States in 1950.[61]

Another assumption important to the calculations is that the group received a doubling dose, whatever level of exposure that is, although there is no magic in the doubling dose for contingent injury fund purposes as there is for such cases if existing rules are used. A linear curve also is assumed, as seems reasonable for legal purposes, at least at exposure of 50 or more units. The contributions to the fund should be calculated on the actual increased risk resulting from each defendant's source and this will depend

61 100,000 was used because the statistical calculations in scientific literature are based upon this or a larger number of persons. If a large scale nuclear incident, such as a reactor burn-up or waste disposal accident, should occur near a large population center, 100,000 persons could be exposed to fairly large doses of radiation and possibly could make claims under ordinary tort rules. On the other hand, in the occupational situation typically covered by workmen's compensation acts it is unlikely that in any given year more than 100 or possibly 1,000 workers would be exposed, at least to levels above 50 units. The interpolation of results from 100,000 to 1,000 or 100, however, is simple and from the standpoint of proving biological causation there is no real difference between the two situations, provided large enough samples are included.

The calculation of the natural incidence assumed a random population. Of course, when handling actual claims arising under ordinary tort principles, account would be taken of the particular victims involved. Thus, variations would be introduced by such facts as: (1) Women have a lower incidence of leukemia than men, VITAL STATISTICS—SPECIAL REPORTS, and therefore if more women than men were actually exposed, the natural incidence among the victims would be lower than the calculation based on a random sample; (2) Both older and very young individuals have a higher than average incidence of leukemia than the middle group, VITAL STATISTICS—SPECIAL REPORTS, and therefore a disproportionate exposure of these high incidence groups would raise the expected natural incidence whereas a predominance of the middle group would lower the expected natural incidence; (3) Any possible effect of an inherited tendency toward malignancies must be ignored for administrative reasons.

on the actual dose received by the potential victim. Nevertheless, a doubling dose has been assumed because some exposure level has to be used and, in any event, the natural incidence figure must be calculated when applying the fund concept. Also, more is known about the effect of radiation on leukemia incidence at levels of the doubling dose and higher, and scientists feel more confident about assuming linearity of the curve at these levels.

Further assumptions are that no cases appearing during the first two years after exposure are attributable to the irradiation and that twenty years is the maximum latency period for radiation-caused leukemia. It is possible that the years one to fifteen are equally reasonable.[62]

The use of 1950 census figures adds an error because of the higher incidence of leukemia at the present time, but this will not affect in any way the validity of the calculations for purposes of demonstrating the feasibility of the basic concept of the fund. If the fund were used it would be a simple task to make new calculations when the 1960 figures are available.

A last important assumption is that in normal personal injury cases the award to each victim who contracts leukemia will be $20,000. This seems to be a reasonable estimate of an average figure if no payments are made for death as such but lost wages and adequate compensation to dependents deprived of support are included. If a different figure is used the dollar amounts will change but the basic concept of the fund is not affected. Certainly the amount awarded in ordinary tort cases might vary from case to case while in workmen's compensation situations a scheduled award probably would be made. The basic concept of the fund can be used in either event.

b. *Ordinary personal injury cases under the contingent injury fund.* Using the above assumptions, if a random group of 100,000 persons were exposed to a doubling dose of radiation, 143 of the group are potential future victims of leukemia, if all lived the full twenty years.[63] In addition, of course, 143 cases would arise from natural incidence causes, making a total of 286 victims potentially claiming compensation. Defendants should contribute

[62] We have to wait until 1965 to know whether radiation-induced leukemias can occur after twenty years for it will then be twenty years after Hiroshima and Nagasaki. Heyssel reports that through the year 1957 the incidence was still elevated among the exposed Japanese, Heyssel, *supra* note 20, at 327.

[63] Note 52 *supra*.

143 × $20,000 or $2,860,000. An additional $2,860,000 would have to be contributed for the natural incidence cases so that each of the 286 who get leukemia — there being no way to differentiate the radiation-caused and natural incidence groups — could be paid a full $20,000. If a tripling or quadrupling dose were received by all 100,000, defendants' contributions would have to be $5,720,000 or $8,580,000 respectively.

Actually 143 claims will not be made by leukemia victims who have received a doubling dose because some of them will die of other causes unrelated to radiation. The same is true of the natural incidence number. Using mathematical calculations which are accurate enough for legal purposes, it is found that only 107 of the potential 143 victims will survive to die of leukemia, whether within the irradiated or the natural incidence group.[64] The dollar amount is therefore reduced to $2,140,000 for each of these groups.

If defendants are required to contribute for the full number of potential victims caused by their radiation, which was one of the possibilities suggested for financing the natural incidence number, for each doubling dose of the group contributions would have been made for about 36 cases which actually will make no claim against the fund later. This means that the contribution that must be made to cover the natural incidence cases could be reduced by 36 cases, or $720,000, for each 50 units of radiation (assumed to be the doubling dose) to which the group is exposed. The basic unfairness of charging defendants' with 143 instead of 107 cases was explained above. In addition there is considerable uncertainty as to what levels victims of accidents will be exposed and the fund could hardly be financed on the assumption that a large group would receive a tripling or quadrupling exposure.

In considering how to finance the 107 natural incidence cases, assuming that defendants will not be forced to become insurers against leukemia in the exposed population, further reductions

64 This is not strictly accurate because the radiation-induced leukemias predominantly show up four to eight years after exposure while the naturally occurring cases are scattered more evenly throughout the twenty-year period. Therefore, calculating the number of potential radiation-induced leukemia victims who die before contracting the disease does not result in exactly 36; the exact calculation is not possible.

may be made. There is good evidence that of the four major types of leukemia, one, chronic lymphocytic, is not caused by irradiation, at least at levels of 50 units or greater.[65] If this evidence is accepted for legal purposes, as it probably should be at present, the 107 natural incidence or doubling dose number is reduced to 76 for the next twenty years after exposure for 100,000 exposed persons.[66] Also, if fifteen years is found to be the maxi-

[65] See note 42 *supra.*

[66] The VITAL STATISTICS—SPECIAL REPORTS do not break down the cause of death from leukemia into the various types of leukemia. In order to make an estimate of all cases of leukemia except chronic lymphatic it was necessary to use the data of MacMahon & Clark, *Incidence of the Common Forms of Human Leukemia,* 11 BLOOD 871, 877 (1956), to derive the percentage of chronic lymphatic leukemia in the total incidence of leukemia in various age groups. An approximate calculation was then carried out by subtracting these percentages from the expected rate of leukemia for each age group. However, the figures of MacMahon and Clark are broken down into 10-year periods different from those found in VITAL STATISTICS—SPECIAL REPORTS. Therefore, an exact calculation would entail redoing the former calculation with the rates changing every five instead of every ten years. The approximate figure set out was obtained by correcting the figures of the old calculation and estimating the errors introduced by this procedure. Both the figures of MacMahon & Clark and the approximate incidence of all leukemias excluding chronic lymphatics are reproduced below.

MACMAHON & CLARK
(per 100,000)

Age	Chronic Lymphatic	Total	Percentage
0-9	.03	4.92	.6%
10-19	.00	2.68	0.0%
20-29	.05	1.81	2.8%
30-39	.36	3.38	10.7%
40-49	.85	5.29	16.0%
50-59	2.90	10.86	27.3%
60-69	7.61	19.16	39.7%
70+	11.40	24.11	47.3%

Percentage decrease due to chronic lymphocytics

$$30\text{-}39 = \frac{3.6}{33.8} = 10.7\%$$

$$40\text{-}49 = \frac{8.5}{52.9} = 16.0\%$$

$$50\text{-}59 = \frac{29.6}{108.6} = 27.3\%$$

$$60\text{-}69 = \frac{76.1}{191.6} = 39.7\%$$

$$70+ = \frac{114.0}{241.1} = 47.3\%$$

mum significant latency period, as it might be, the doubling dose figure is again reduced to 75 from 107.[67] If these two reductions are combined, which may not be unrealistic, the number of natural incidence cases that will be indistinguishable from radiation-

Age	Incidence (of leukemia but with chronic lymphocytic left out)
0-5	4.8
5-9	3.8
10-14	2.8
15-19	2.6
20-24	3.0
25-29	3.9
30-34	4.5
35-39	6.4
40-44	6.6
45-49	6.8
50-54	7.9
55-59	7.2
60-64	6.4
65-69	4.8
70-74	2.4
75-79	1.2
80-84	.4
over 85	—
	Total 75.5

67 The 15-year approximation was obtained not by redoing the calculation, but by estimating how many leukemias would be eliminated from the 20-year figures by discounting the last five years.

15 Year Figures

Age	Natural Incidence	% of Population
0-5	3.6	10.7%
5-9	3.0	8.7%
10-14	2.0	7.3%
15-19	2.3	6.7%
20-24	2.2	7.3%
25-29	2.9	8.0%
30-34	3.3	7.3%
35-39	4.2	7.3%
40-44	5.3	6.7%
45-49	7.1	6.0%
50-54	8.0	5.5%
55-59	8.5	4.7%
60-64	9.2	4.0%
65-69	7.4	3.3%
70-74	4.3	2.0%
75-79	2.0	1.3%
80-84	.6	.67%
over 85	—	.33%
	Total 75.9	

induced cases will be only 50 to 55.[68] This reduces the dollar contribution from $2,140,000 to a little more than $1,000,000 for the fifteen-year period.

If the preferred solution suggested above for handling the natural incidence figure were accepted, the contribution required of each of the 100,000 potential victims would be very small, even if 107 is used as the natural incidence figure. If each paid $21.40,[69] representing the risk each had of getting leukemia even if he had not been irradiated, the necessary $2,140,000 would be available later to compensate the natural incidence victims; the defendants would have contributed the other $2,140,000 to cover the 107 radiation-induced cases. If either chronic lymphocytics are excluded or the fifteen-year period is chosen, each person wishing to claim against the fund later if he contracts leukemia (other than chronic lymphocytic leukemia, should that be excluded) would need to contribute only $15[70] and the fund would be large enough to pay the 75 natural incidence victims. If both reductions were made a contribution of only $10 to $12 would be necessary.[71]

However the natural incidence cases are financed, use of the contingent injury fund would make it possible to avoid attempting the impossible, proving biological causation for specific cases.

c. *Workmen's Compensation Cases Under the Contingent Injury Fund.* The same basic solution to the causation problem is possible in the occupational exposure situation, although existence of a closed group of potential victims makes possible a slight variation in accounting for the natural incidence cases.

Claims arising from exposure of workers in the nuclear industry could be handled in the same manner as normal tort liability cases, although some slight modifications would be required.

[68] $\frac{107}{75} = \frac{75}{X}$ gives a close approximation.

[69] 107 x $20,000/100,000 = $21.40.

[70] 75 x $20,000/100,000 = $15.

[71] 50 x $20,000/100,000 = $10.
60 x $20,000/100,000 = $12.
All of the calculations have been made without considering either administrative expenses or interest earned by accumulated funds. In practice these must be considered (they may even cancel each other), but this does not affect the validity of the contingent fund idea.

Assuming for ease of calculation that the industry eventually employs 100,000 workers, a minor correction should be made in calculating the natural incidence rate if the contribution for this figure is calculated on the basis of the whole group rather than each individual exposed. The work force very likely would consist of men between the ages of 25 and 65, not a random sample of the population. Accepting the $20,000 recovery figure, these corrections probably would change the natural incidence figure somewhat.[72] Some amount of exposure, such as the maximum permissible levels, would have to be selected to determine which workers were to be considered potential victims of leukemia. This would be necessary to fix the amount of contributions by both the employers and the workers. The contribution of the worker would be in the neighborhood of $20 for the twenty-year period, while the employer's assessment would be in accordance with the level of overexposure.

A slightly different scheme, which in some ways is simpler to administer, could be used with such a closed group. Using the 1950 census incidence figure of 5.7 cases of leukemia per year per 100,000 persons,[73] $114,000 worth of leukemia would occur each year. If each employee in the group would contribute $1.14 each year the natural incidence figure would be covered. The employers would be responsible for all additional cases of leukemia among the employee group and would contribute accordingly.

[72] If retirement is used as a cut-off point for recoveries, then many of those accidentally exposed will not be covered for the full twenty-year period. This will result in a reduction of the natural incidence figure, as well as the number caused by radiation exposure. On the other hand, although the incidence rates for men are higher than for a random sample of the population, they are not enough so to cancel the effect of retirement. If recoveries are extended beyond retirement age, then the natural incidence will be above 107. This is due both to the higher incidence of leukemia in men and to the elimination in the sample of the younger age groups.

[73] The incidence of leukemia in males used for this calculation is also from VITAL STATISTICS—SPECIAL REPORTS.

Age	Total Cases/ yr./100,000	No. in Work Force	Percentage of Work Force
25-29 } 30-34 }	.8	16,100	16.1%
		15,300	15.3%
35-39 } 40-44 }	.9	14,900	14.9%
		13,500	13.5%
45-49 } 50-54 }	1.5	11,900	11.9%
		10,900	10.9%
55-59 } 60-64 }	2.5	9,500	9.5%
		7,900	7.9%
	5.7 cases	100,000	

One real advantage of this approach is that it would avoid altogether the necessity of individual determinations of the existence of exposure and the amounts thereof. The only determination required would be that one of the workers had leukemia. This plan avoids all of the really difficult litigation matters discussed next.

Some difficulties exist in such an approach. One is that instead of reducing the natural incidence figure by the expected mortality among the exposed population who would have contracted leukemia, the raw annual incidence figure, 5.7 in 1950, must be used. The group remains stable with a constant composition each year because as one worker drops out of the group (for whatever reason) another takes his place and 5.7 cases of leukemia would occur in this group each year. Likewise, in fairness something should be done to cover those workers who do leave the work force but later contract leukemia within the latency period after their last employment in the nuclear industry. Perhaps this could be handled by requiring any such employee who wants to be covered after leaving the group to continue his annual contributions for natural incidence and then making the employer group cover his case if leukemia occurs. A last possible objection is that if this plan is to work the whole employer group would have to be included and payments made without reference to actual overexposures caused by various members of the group. This forces the careful company to pay for exposures caused by others who perhaps are not as careful.

Whichever approach is adopted, the contingent injury fund result is preferable to that reached by applying existing rules. If the group received slightly more than a doubling dose the industry would have to pay $114,000 each year for leukemia cases not caused by radiation, and if just less than a doubling dose were received, and even if a wait-and-see doctrine were used, $114,000 worth of radiation-induced leukemia damage manifested each year would go uncompensated. It may be argued that $114,000 a year is a relatively small burden for either an industry employing 100,000 persons, or for a group of 100,000 employees. If in addition, however, other latent, non-specific diseases which can be caused by radiation exposure are included, as eventually they will be, the total figure may not be so painless. Merely including other forms of cancer which can be caused by irradiation will increase the burden greatly because cancer is a major cause of death.[74] If a correlation should ever be found between irradiation and coronary heart disease,[75] the burden would be very serious because this is the largest killer of all causes in the United States.[76] Such a burden begins to make the employer a kind of insurer of his employees against death, or forces employees to go uncompensated for a significant amount of injury.

d. *Statistical Uncertainties.* The determination of the contribution which the defendants must make to the fund to cover the increased risk is made difficult and somewhat uncertain because of three major gaps in our present scientific knowledge about the effect of radiation as a cause of leukemia: (1) Is the dose-rate curve linear (straight) or curved? (2) Is there a threshold level below which no increased incidence of leukemia occurs? (3) Is the increased incidence less if the exposures are chronic (a series of exposures spread out over a period of time) as opposed to acute (all at once)? Any one or a combination of these uncertainties makes the calculation of the proper contribution less than certain.

The significance of these uncertainties is illustrated by the difference in contributions required depending on whether the doubling dose is 30 or 80 units. The most logical choice, which surely would have to be chosen at the present time under existing rules, is the average, 50-55 units. If this figure were used but the higher figure is correct at least the fund or insurance companies would have sufficient funds to pay all claims and have a surplus as well. If 30 units proves to be the actual doubling dose then insufficient funds will be available to compensate all cases of leukemia that will arise. This difficulty might be solved in either of two ways: (1) by assuming the lower figure and possibly giving a windfall to the fund or the insurance companies, or (2) having the government underwrite this contingency in the sense that, if the lower figure proves correct, the government will make the additional contributions necessary and if the higher one is right, the surplus could go to the government. This could be done even if the insurance policy method of funding the basic contingency scheme were adopted.

74 Metropolitan Life, 41 STATISTICAL BULLETIN 3 (1960).

75 Dublin & Spiegelman, *Mortality of Medical Specialists 1938-1942,* 137 J.A.M.A. 1519, 1523, 1524 (1948). For the period 1938-1942 both radiologists and dermatologists have abnormally high incidences of coronary disease when compared with other medical specialties. The possibility cannot be excluded that this increase is due in some measure to their occupational exposure to radiation.

76 See note 74 *supra.*

When applying the contingency injury fund concept, however administered, the doubling dose is not important except as an example of results to be reached and what effect scientific uncertainties will have on these results. The important thing is the accurate prediction of the effect of irradiation on the leukemia incidence rate at all levels of exposure. The two solutions suggested could be applied to prediction of the increase at all dose levels.

The uncertainty as to the existence of a threshold level below which no increase in leukemia occurs also makes calculations possibly inaccurate. The number of cases that will be "caused" by very low level exposures if no threshold level exists is so small, however, that for present purposes the law should assume that there is none. This will assure sufficient funds to compensate all cases and even if there is a threshold the windfall to the insurance companies or the government fund will be very minor in amount. Again this could be solved by having the government underwrite this uncertainty as was suggested with the dose-rate curve unknown.

As to the possible difference between the effect of chronic and acute exposures on leukemia incidence, at the present time, with no satisfactory evidence indicating a difference, the same conservative or pessimistic approach should be taken; there is no difference. This uncertainty could be handled in the same manner as the others.

An additional difficulty in calculating contributions to be made to the fund is that of random fluctuations, a problem with any use of statistical correlations. If the fund's coverage is large enough, then these statistical variations will not be serious. Undoubtedly, however, this means the coverage will have to be at least multi-state, if not national in scope.

These difficulties arising from inadequate scientific knowledge certainly cannot be ignored and do create problems in applying the contingent injury fund to radiation injuries. This is no reason for rejecting the fund concept, however, because these exact same difficulties also will plague the administration of such injuries under existing rules. In fact, under present rules there is much less flexibility and these scientific uncertainties probably will result in greater injustice than under the fund concept. The only possible advantage of accepting the traditional approach, other than whatever advantage inheres in inertia, is that the errors get buried once and for all upon conclusion of the case, whether they are slight or gross. In the kinds of situations here discussed they are likely to be gross. If the fund is used the actual extent of the error will be shown because of the wait-and-see aspect of the concept. Providing for these uncertainties as suggested above, however, is not so difficult as to justify accepting results under existing rules which are so unrealistic and unjust.

III. LITIGATION DIFFICULTIES FOR INDIVIDUAL CASES

Once the general problems of damages and proof, including proving biological causation, have been resolved as satisfactorily as possible, and regardless of how they are resolved, the evaluation of individual cases will present additional significant difficulties. These alone are great enough to necessitate a reconsideration of some aspects of existing personal injury litigation procedures, regardless of how the biological causation uncertainty is handled. Some changes should be made.

A. *Difficulties*

Determining the amount of exposure of the plaintiff in a particular accident is often, if not usually, extremely difficult. Studies of the irradiation of human beings at Hiroshima and Nagasaki and attempts during United States nuclear arms testing programs to determine the human dosage in a nuclear bomb release situation indicate that if a major accident happens in a large population center the determination of how much irradiation each person received is at least difficult and perhaps impossible.[77] The degree of shielding, among other things, is extremely important and yet even educated guesses are most difficult to make. These difficulties should not be as great as in the Japanese studies, however.

In many of the occupational exposure cases it will be necessary to reconstruct the accident and our experience in the United States in some of the cases that have occurred indicates that it will not always be easy to determine exactly how much exposure an individual received,[78] although some progress is being made in calculating the amount of radiation exposure by using such in-

[77] Arakawa, *Radiation Dosimetry in Hiroshima and Nagasaki Atomic Bomb Survivors,* 263 NEW ENG. J. MED. 488 (1960). See also Hurst, Pitchie & Emerson, *Accidental Radiation Excursion at the Oak Ridge Y-12 Plant-III,* 2 HEALTH PHYSICS 121 (1959).

[78] Notes 1 and 77 *supra.* See also McLendon, *Accidental Radiation Excursion at the Oak Ridge Y-12 Plant-II,* 2 HEALTH PHYSICS 21 (1959).

ternal indications as the amount of radioactive sodium in the victim's body following the accidental exposure to neutrons.[79] Even in the radiation diagnosis or treatment situation sometimes it is difficult to determine exactly how much a person has received, particularly when only one section of the body has been exposed and the whole body dose must be interpolated from this.

Another litigation difficulty arises with regard to the basis for determining how much effect on the body a given amount of radiation has, assuming the amount can be determined. This is called the relative biological effect, or rbe, and scientists do not agree as to what the rbe is of various types of radiation and for specific parts of the body.[80] This becomes crucial when a victim is exposed to more than one type of radiation, perhaps internally as well as externally.

In addition, there are the *relatively* simple problems of proving how much radioactive material escaped, which involves an analysis of the shielding, how much radiation came from these materials, how long the person was in the presence of the radiation, how far away from the source he was, whether it was a skin dose of low or high level radiation, whether it was an internal or external exposure or both, and similar "facts." All must be determined and evaluated when legally fixing a person's exposure. The calculation of the increased chance of diseases such as leukemia is based on such findings. These difficulties, however, great as they may be, are no worse for the contingent injury fund scheme than for normal personal injury litigation procedures, whatever the present scheme for handling these cases in various legal systems may be.

The great technical complexity involved in determining the increase in likelihood that the plaintiff will contract leukemia as a result of a particular radiation exposure raises a serious question as to the ability of existing litigation tribunals, made up of juries and judges, none of whom are likely to be trained scientists, to handle radiation cases. The difficulties involved in estimating the increase of leukemia from a given amount of exposure have

70 Saenger, *Radiation Accidents,* 84 AM. J. ROENTGENOLOGY 715, 722 (1960). The article analyzes the 77 radiation accidents in 13 years of AEC operations. Saenger describes the various possible indices of the amount of exposure in human beings.

80 Bond and others, *Distribution in Tissue of Dose from Penetrating Bomb Gamma and Neutron Radiations, Proceedings of the Vanderbilt University Medical School Symposium on Radioactivity in Man,* held in April 1960, and yet to be published. This paper indicates a line of experimental work that is attempting to develop more accurate data on the absorption of neutrons by the various organs of the body.

already been stated, although it should be emphasized that approximations in this area are possible, and probably are more accurate than the information upon which the insurance industry now calculates its premiums, other than for death. The data obtained at Hiroshima and Nagasaki and from other radiation situations, in spite of the arguments of the scientists as to their proper interpretation, provide good figures from which to make reasonable legal estimates.

The additional major physical technical difficulties encountered in measuring the amount of radiation affecting the victim also are too difficult for the untrained person. Reconstruction of the accident is hard enough but even when the circumstances are known with some accuracy, complicated formulas must be used to determine the exposure. This is determined from the frequency and intensity of the gamma rays, alpha and beta particles, and possibly neutrons, both externally and internally, all as a function of distance from the radiation source. Additional complexities are introduced into the calculations when account is taken of the shielding that may have been present.

These difficulties of calculation are great enough but those of determining the damage to body tissue from the absorbed radiation are even greater. For leukemia the blood-forming organs are the critical ones. The absorption of gamma radiation depends upon the frequency of the waves and although complicated approximation formulas have been developed by radiologists, the absorption coefficients necessary for these formulas are known only roughly. Beta particles are not very penetrating and probably can be ignored for purposes of leukemia, if from an external source. Neutron penetration presents another story because experimental work on neutron effects is less complete than for gamma rays, but neutrons are penetrating and they do severe damage. In short, difficult calculations must be made to determine the amount of energy absorbed from a particular radiation accident by the whole body and particularly by the blood-forming organs for leukemia.

Therefore, even if biological causation difficulties are overlooked, the problems of physics and biology that remain are formidably technical. The terminology of the physicist is learned only through years of training in the physical sciences. The same is true for biology and medicine, although their terminology perhaps is a little more familiar to the laymen. All three areas are becoming increasingly more technical. Nuclear technology, although only a generation old, is the product of three centuries of physical thought and already is much too technical for the layman to understand.

Procedures for proving biological causation need to be changed as indicated before, but even if this is not done, these difficulties of litigating individual cases involving radiation injuries should, without more, lead legislators to consider seriously the possibility of modifying litigation procedures which permit such technical questions to be decided by various lay groups. In the United States usually a jury or possibly a judge makes such decisions. Much could be left for determination by such lay tribunals. Scientists and other specialists have no better, if as good, judgment as laymen and lawyers on such questions as which injuries or diseases should be compensated and what the value of such a disability is. But the latter groups are ill-equipped to evaluate various and often conflicting positions taken by scientists. Such scientific conflicts cannot be resolved well by typical jurors, and probably not even by the typical judge. Certainly this seems true for making the best estimate of the incidence of leukemia (and similar diseases), and the dose-rate relationship to irradiation. Even the determination of the amount of exposure and its effect probably is too difficult for these lay groups.

If the contingent injury fund were adopted, an additional reason exists for changing lay determinations of the scientific "facts," although not necessarily the compensability and value of various injuries. Once legal liability and compensability of the injury are determined, the scientific facts of increased incidence determine the amounts of money which must be contributed by the potential defendants and plaintiffs (or other source which contributes for the natural incidence cases). The fund must be sufficient to pay for the future cases of leukemia among the exposed group. The amount of such contributions must be made on the basis of an *expert* appraisal of the best available scientific evidence, not one by a layman selected to decide an isolated case.

B. *Some Suggestions for Changes*

The existing system of lay jury, judge, or tribunal determination should be modified at least to some extent. A panel of experts, which would include not only scientists but also some lawyers, should be created to make a basic judgment as to the best present scientific estimate, *for legal purposes,* of the incidence of leukemia and its relationship to radiation. It is unlikely that the best scientists (and only their views should be used) would be willing to serve permanently on such a board if it handled all cases. Perhaps the group could meet once a year, however, to decide what changes in the previous estimates, if any, have taken place during the interim between such meetings. The determination of incidence, relative biological effect, and other scientific "facts," would be handled by this independent scientific-legal group. The determinations of this group might then be accepted in every trial, possibly leaving to the normal litigation processes only those determinations which vary from case to case. Such an expert panel should make these findings of basic scientific facts only after a public hearing in which plaintiffs' and defendants' lawyers, as well as other interested groups, including government personnel, are given an opportunity to argue for their points of view and to present the evidence most favorable to their group. Certainly, it is utterly unrealistic to turn over to lay juries, judges, or tribunals who have no particular experience with such diseases and radiation, the job of determining what the best scientific guess is.

In addition, the complicated but less theoretical determination of some of the facts which vary from case to case, such as the actual exposure of the particular plaintiff, probably should be made by an impartial tribunal of experts. It would not be necessary to have the top biologists, physicists and similar scientists on this panel. Probably these determinations could best be made by an impartial tribunal of health physicists and other radiation protection experts. Lawyers would continue to represent their clients' interests but before experts who understood the technical aspects of the case.

At first these suggestions may appear to be destroying our existing litigation processes in personal injury situations. Such is not the case. The determinations which represent the human value judgments of the community, such as liability and compensability and value of various injuries, could be left to groups such as juries and judges who represent the community's opinions. It would be simpler to administer the fund if fixed values were attached to a case of leukemia, more or less regardless of the circumstances of the individual victim, as is now done in most workmen's compensation schemes, but this not necessary. The important thing is to determine immediately how much will be awarded if leukemia ensues and what are the chances of it occurring after the exposure. This could be done on an individual basis, varying from case to case with such factors as age, earning capacity, number of dependents, etc. Insurance companies now adjust their rates for insurance coverage in the personal injury field in accordance with these variables in jury-awarded verdicts. The same procedure could be used even more accurately and fairly under the contingent injury fund idea by making use of the best expert estimates of the natural and radiation-induced incidence of such diseases, the scientific aspects which should be constant for all similar cases.

None of these suggestions call for abolishment of the litigation system now used, which is based on compensation for injured individuals in accordance with individual determinations of liability and value of the disability. The costs of the litigation process, as the few studies in this area clearly show,[81] are at least discouraging if not shocking, and someday it may be proved that it is cheaper, even for defendants, if health and compensation insurance schemes involving no litigation are adopted. It is too soon yet to determine whether or not this is true and it is not necessary to abandon but only modify our existing system to achieve better administration of justice in radiation injury cases.

CONCLUSION

This discussion has posed various policy questions relating to radiation-induced injuries in the hopes of stimulating the thinking of the bar and the legislatures on these fundamental and mostly ignored matters. These groups have very little time left in which to decide what damages to compensate and how to prove and administer the awards to be made, if the law is to avoid the charge so often leveled at it and frequently properly so, that the legal system lags badly behind developments in the other sciences, including the physical and biological.

The contingent injury fund concept handles more satisfactorily than existing rules the twin problems created by the latent and non-specific characteristics of leukemia. The possibility of extending the fund idea to other similar radiation injuries such as cancer and genetic damage is suggested. The concept should help the law not to lag but rather to play its proper role of making it possible for society to assimilate intelligently and with justice the technological advances brought on by the splitting of the atom.

81 Conard, *The Impact of Expense on Injury Claims,* 287 ANNALS AM. ACAD. POL. & SOC. SCI. 110 (1953); Conard, *Workmen's Compensation: Is It More Efficient than Employer's Liability?* 38 A.B.A.J. 1011 (1952); Conard, *The Economics of Injury Litigation* (preliminary ms. 1960).

If a scientifically more accurate solution to the problems of damages and proof of causation in radiation injury cases is developed, perhaps some better insight into other types of injuries which now are being handled under probably antiquated procedures may be gained. The kind of bad guesswork that will have to be applied to radiation cases under existing rules undoubtedly has been used more often in the past than we care to admit in standard personal injury cases. Translation of biological cause to legal cause often has not been done very satisfactorily, as evidenced by the mutual mistrust and criticism existing between the experts and lawyers and even within the bar itself as to injury litigation concepts. Because such injuries had not the magic labels atomic, or nuclear, or radiation, and because many persons mistakenly felt that the frequent occurrence of such injuries in everyday experience made it possible for almost anyone to understand them, this problem of biological causation has attracted insufficient attention from those who make and administer the law. If the radiation injury problem can be solved fairly and with scientific realism, possibly a substantial contribution to the administration of justice in personal injury cases generally also has been made.

In any event, now is the time to face these problems for radiation cases, not after greatly expanded use of this new source of energy has created a large number of cases which the law is ill-equipped to handle.