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PHYSICAL AND CHEMICAL AGENTS AND CARCINOGENIC RISK[1]

E. Somers

Those seeking to detect and control environmental hazards have a growing assortment of tools at their disposal. This article reviews various cases to which these tools have been applied in Canada—such as the carcinogenic dangers posed by chloroform, water fluoridation, saccharin, Tris, and radon—and discusses major strengths and weaknesses of the methodologies involved.

Introduction

Within the last decade, the supreme importance of environmental factors in human cancer has become increasingly recognized, largely as a result of geographic, migrant, and occupational studies. The term "environmental factors," as used above, includes threats from all exogenous sources—not only extrinsic physical and chemical agents, but also life-style factors such as sunbathing, diet, smoking, and drinking (*1,2*). The wide-ranging nature of this definition emphasizes the important contribution made by individual choice. Nevertheless, the accelerating pace of our technological society poses potential and actual threats to human health that raise key problems for the political and administrative machineries of the modern state.

We are now in a chemical era in which the uses of new chemicals—from fabrics to fuels, fertilizers to food additives—have increased dramatically in the last 30 years; in the case of synthetic organic chemicals, for example, these uses have increased over 300-fold (*3*). According to current estimates (*4*), some 60,000 natural or synthetic chemicals are used in daily life; and perhaps 1,000 new chemicals are marketed each year. Many of these chemicals, or their residues, appear in workplaces or in the air, water, food, or soil as contaminants resulting from the processes of production or consumption. Yet, of the more than 100,000 potentially toxic chemicals involved, only some 6,000 have been tested in the laboratory for carcinogenicity (*3*).

Similarly, the range of radiation-emitting devices for professional or consumer use is expanding, and the search for fossil fuel substitutes has led to increasing development of nuclear energy. In many countries the public debate following these developments has focused on the long-term biological effects of ionizing radiation.

Examples of Risk Assessment

To illustrate the mechanisms available for controlling these real and presumed hazards, I should like to provide some examples of Canada's regulatory approach to assessment and subsequent containment of chemical and physical carcinogenic hazards, giving due consideration to the limitations on which these judgments must necessarily be based. I should then like to review the implications of the risk assessment process in a wider context.

Cancer emerges from our collected national statistics (*5*) not only as the second major

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[2] Director-General, Environmental Health Directorate, Health Protection Branch, Department of National Health and Welfare, Ottawa, Canada.

cause of death for both sexes, but also as the leading cause of years of potential life lost for women. In terms of average annual deaths, by cancer site, cancers of the lung, colon-rectum, and prostate cause the greatest mortality among men, while cancers of the breast, colon-rectum, and stomach cause the greatest mortality among women. However, an analysis of 1931-1974 cancer patterns in Canada that used a priority index based on measures of mortality, morbidity, and time-trends showed the most important cancer sites to be the lung and prostate in men, the breast and lung in women, and the colon-rectum in both sexes (*6*).

Canada has seen a dramatic rise in male mortality from lung cancer over the whole of the last 40-50 years and accelerating female mortality since 1960. The evidence is overwhelming that cigarette smoking is largely responsible. However, with reference to carcinogens in food, a continuous decline in the age-standardized stomach cancer mortality rate for both sexes is significant; recently, a report from Saskatchewan for 1950-1975 (*7*) confirmed this trend.

The following are some illustrative examples of carcinogenic risk assessment:

Chloroform and Trihalomethanes

We have recently completed a comprehensive review and reassessment of the 1968 Canadian Drinking Water Standards and Objectives. Trihalomethanes are known to occur in drinking water treated with chlorine. The trihalomethane found most commonly in drinking water is chloroform; and a recent survey (*8*) of some 70 Canadian municipalities showed that the concentration of chloroform in drinking water can reach 0.121 mg per liter. The question thus becomes: Is this an acceptable level?

Epidemiologic studies of the lower Mississippi and Ohio river valleys failed to give unequivocal evidence of a direct cause-and-effect relationship between chloroform contamination of drinking water and a variety of recorded cancers, although suspicions have been raised about possible association with bladder cancer (*9*). However, a U.S. National Cancer Institute rodent study found a dose-related incidence of malignant tumors in male rat kidneys and in livers of mice of both sexes (*10*). The daily dose employed to produce these effects was high—in the range of 100 to 500 mg per kg of body weight. In addition, studies with cough suppressants and mouthwashes have shown chloroform to produce hepatoxicity in humans at oral doses ranging between 1 and 25 mg per kg per day for a 70 kg person; and occupational exposure to chloroform in the pharmaceutical industry is known to produce liver damage among workers (*11*).

Tardiff (*10*) has carried out a detailed analysis using four different mathematical models[3] to determine the maximum risk incurred by drinking tap-water containing chloroform. A tenfold margin of safety applied to liver damage in man would place the maximum acceptable daily dose at 0.03 mg per kg. As Table 1 shows, extrapolation from the rodent studies indicates that the maximum risk at a maximum daily dose of 0.01 mg per kg ranges up to 0.4 cancers per million people per year. For a 70 kg man consuming 2 liters of water daily, this latter intake (0.01 mg per kg) would result if the chloroform concentration in the water were 0.35 mg per liter. Hence 0.35 mg per liter is the recommended maximum acceptable concentration of total trihalomethanes in drinking water. The objective level, i.e., the ultimate quality goal for trihalomethanes, is a concentration less than or equal to 0.0005 mg per liter.

In this example, statistical extrapolation from animal studies to man is defensible because we know the human target organ for chloroform and because there is some evi-

[3] A margin of safety model, the probit/log (Mantel/Bryan) model, a linear or one-hit model, and a two-step model.

Table 1. Use of mathematical models to estimate the maximum levels of risk from chloroform ingestion.

Mathematical model	Animals and organs studied	Estimated maximum risk per million population	Maximum dose
Probit-log (slope = 1)	Rat (kidney)	0.016-0.040 cancers per year	0.01 mg/kg/day
Probit-log (actual slope)	Rat (kidney)	< 0.001 cancers per lifetime	"
Probit-log (actual slope)	Mouse (liver)	" "	"
Linear (one-hit)	Rat (kidney)	0.420 cancers per year	"
Two-step	Rat (kidney)	0.28 cancers per year	"
Two-step	Mouse (liver)	" "	"

Source: R. G. Tardiff (*10*).

dence that similar metabolic pathways are involved. On this basis, we can say that the risk of liver or kidney cancer to a person drinking water containing chloroform lies between no risk and a maximum risk of 1 chance in 2.5 million per year.

Nitrilotriacetic Acid (NTA)

The detergent-builder nitrilotriacetic acid (NTA) is widely used in Canada; current consumption exceeds 50 million pounds annually, most of this being disposed of in sewage. Studies with rats and mice have found that high doses of NTA produce an increased incidence of urinary tract tumors (*12*). In a recent national drinking water survey (*13*), we found a mean concentration of 2.8 μg NTA per liter. Assuming a concentration of 50 μg NTA per liter (a higher concentration than that reported for at least 99 per cent of the drinking water samples tested), and making no allowance for the reduced absorption of the compound by humans as compared to rodents, the daily intake for a 70 kg man drinking 2.0 liters would be 0.001 mg per kg. Using the linear arithmetic model, the probable maximum risk of cancer resulting from this intake would be about 1 chance in 2 million. The safety factor for other effects of NTA—based on biochemical and histological changes—is about one in 10,000. A maximum acceptable concentration of 0.05 mg per liter has therefore been recommended for NTA. The objective (ultimate quality) concentration is below 0.0002 mg per liter.

Water Fluoridation

Fluoridation of drinking water has long provided a battlefield for public controversy. This health measure was introduced in Canada in 1945, and today some 46 per cent of those relying on public water supplies receive fluoridated water (*14*). Yiamouyiannis and Burk (*15*) claimed that fluoridation increased cancer rates in the United States, but this allegation has not withstood critical analysis (*15,16*). We have examined the cancer mortality data from some 79 groups of municipalities—comprising over 300 separate municipalities and representing a population of 12.4 million—throughout Canada (*16*). Comparison of 1954-1973 death rates for some 58 per cent of the Canadian population—with regard to all types of cancer and cancers arising at specific sites—showed no appreciable death rate differences between inhabitants of fluoridated and non-fluoridated municipalities. Nor were any significant differences found between death rates from all types of cancer within any given group of municipalities before and after fluoridation.

Nitrosamines

The Federal Government of Canada has the responsibility under the Hazardous Products Act to provide protection against dangerous consumer products. Synthetic cutting fluids—used to reduce friction during metal grinding—usually contain ethanolamines as emulsifiers and nitrite as a corrosion inhibitor. These components can react to produce high concentrations of the carcinogenic nitrosamines. Fan et al. (*17*) have reported finding up to 3 per cent N-nitrosodiethanolamine in cutting oils; our analyses (*18*) of 24 samples showed that 8 contained this compound at concentrations up to 0.5 per cent. Although N-nitrosodiethanolamine has a lower carcinogenic potential than other nitrosamines, all of a group of rats fed the substance at a rate of 100-200 mg per kg per day developed liver tumors (*19*). We do not know the extent of worker intake of this nitrosamine, via inhalation or the dermal route, but the level and severity of presumed risk was sufficient to prompt a proposed ban on the simultaneous presence of nitrites and ethanolamines in cutting oils.

Tris

Similar considerations led to a ban on the use of Tris(2,3-dibromopropyl) phosphate, a flame retardant for textile fabrics used in children's clothing. U.S. National Cancer Institute studies have found the commercial form of Tris carcinogenic to rodents, mutagenic to ion test systems, and capable of being absorbed by the skin.

Saccharin

The well-known Canadian decision to remove the artificial sweetener saccharin from foods, drugs, and cosmetics was based on studies in which rats were fed a diet containing 5 per cent sodium saccharin for two generations (*20*). Male rats of both the parent and second generations showed a significant incidence of bladder tumors. The dose of saccharin exceeded human exposure by at least 800 times—if one assumes a human consumption equivalent to one bottle of "diet" drink per day. Although other corroborating data were available, this was the key experiment that led to the regulatory decision—at a time when some 200,000 pounds of saccharin a year were being used in Canadian foods.

Polychlorinated Biphenyls (PCBs)

PCBs are persistent and ubiquitous environmental contaminants whose uses were limited by the Environmental Contaminants Act in 1977 to closed electrical and heat-transfer systems. There is some evidence that PCBs produce carcinomas in rodents, and concern has been raised about their transplacental toxicity following the Yusho incident in Japan with contaminated rice oil and studies with monkeys (*21*). A Health Protection Branch survey of human milk found PCB levels up to 68 parts per billion, the average level being 12 parts per billion (*22*). New regulations have just been proposed that would effectively ban all new uses of PCBs; if adopted, these regulations should help to reduce the level of PCBs in the environment.

Ionizing Radiation

The assessment of risk for ionizing radiation is based on a securer foundation than that for chemical carcinogens—in that the biological hazards of radiation for human populations have been well (and often tragically) demonstrated, and in that the dose-effect relationships involved have been established. The reports of the Advisory Committee on Biological Effects of Ionizing Radiation (*23*) and the recommendations of the International Commission on Radiological Protection provide extremely detailed and well-constructed estimates of risk.

For example, in 1972 a survey of ionizing radiation devices in Ottawa schools revealed

that a large number of machines were used in demonstrations. Among these were unshielded cold-cathode X-ray tubes whose maximum exposure at a distance of 30 cm was 4 to 35 roentgens per hour. This could result in an average absorbed dose for children watching the demonstration of up to 1 rem. For each child, this could be translated into a risk of developing fatal cancer amounting to one chance in 10,000 per year as a result of this single exposure. This was regarded as sufficient justification to regulate these devices, which had to be controlled at the manufacturing level. As a result, regulations establishing design, construction, and functional standards for demonstration-type gas discharge devices were promulgated under the Radiation Emitting Devices Act in February 1976.

Radioactivity in Drinking Water

We have used this statistical approach to risk estimation for deriving guidelines on drinking water radioactivity. There is a great deal of information about most of the radionuclides found in drinking water (Ra-226, I-131, Cs-137) with regard to their metabolic fate after ingestion by humans. Hence the known parameters on a given radionuclide's distribution and retention within humans may be used to calculate an annual radiation dose over a lifetime. Estimates from the aforementioned reports on the biological effects of ionizing radiation (*23*) give the excess annual number of cancer deaths for a population exposed to a radiation dose of 200 millirems per year as within the range of 15 to 35 per million. By combining the parameters for concentration-dose with those for dose-health effects it is possible to derive a concentration-health effects relationship. Therefore, we have derived guidelines for acceptable concentrations of radioactivity in drinking water at a specified level of risk; namely, one cancer death per million people per year.

Radon and Radon Daughters

There is epidemiologic evidence that exposure to radon and its daughters may result in lung cancer. It has been shown that uranium and fluorspar miners in Canada are at risk, and federal authorities have established a maximum permissible exposure to radon daughters for uranium mine and mill workers of 4 working-level months (WLM)[4] per year and 2 WLM per quarter. A recent re-evaluation of the Newfoundland fluorspar miners in St. Lawrence showed both extremely high estimated WLM exposures and some 65 lung cancer deaths among underground miners—as compared to 6.4 deaths that would have been expected among unexposed surface workers (*24*); the mine was closed last year.

Radon and radon daughters can also be present in communities not involved in uranium mining. In fact, radon and radon daughters formed from traces of radium in rocks and soils are a major part of the material responsible for naturally-occurring background radioactivity in the air of the lower atmosphere. A survey we made (*25*) of some 10,000 homes selected at random in 14 Canadian cities showed that over 13 per cent of the homes had radon daughter levels exceeding the 0.02 WL used as the reference level for uranium mining communities. However, internationally accepted estimates of risk suggest that the number of cancers and genetic defects induced in the general population by natural background radiation are not more than about 1 per cent of the number of cancers and genetic defects normally present in that population (*26*).

Asbestos

The most notorious physical carcinogenic agent is asbestos, and Canada is the second

[4] A working level is a unit of measure for alpha radiation from radon daughter products to which a miner is exposed.

major producer of asbestos in the world. Regarding asbestos regulation, Canada's Department of National Health and Welfare has recommended a standard of 2 fibers per cubic centimeter, both for the workplace and for outdoor emissions by mining and milling operations. The use of asbestos in modeling clays and children's toys has been banned, and similar action has been proposed for asbestos wall-patching compounds. A survey by Wigle (*27*) of cancer mortality in Quebec, in which subjects were grouped by evidence of exposure to asbestos fibers in municipal water supplies, did not show an association. However, we are now planning to embark on a more comprehensive investigation of the results obtained by analyses of asbestos fiber content of drinking water in some 75 municipalities across Canada.

Risk Assessment and Animal Models

The foregoing are some examples of the manner in which a government regulatory agency arrives at a risk assessment for an environmental hazard and then pursues control measures. You will note that many of the judgments were based on animal experiments, which in turn raises two fundamental questions: How valid are the comparisons of man and animal? and How legitimate are the extrapolations from high to low doses?

Although the basic biological processes of molecular, cellular, and organ function are similar in diverse mammalian species, there are marked differences between humans and the standard rat model for toxicity tests. The rat strain is homogeneous; and it is maintained in a carefully controlled environment with virtually uniform diet, light, sound, etc., so that the insult received is restricted to a single causative factor (*28*). In some senses the more sophisticated the test the more limited its application. Nevertheless, nearly all of the 26 chemicals or industrial processes listed in Table 2—those that have been positively associated with human cancer through the program of the International Agency for Research on Cancer (*29*)—are known to be carcinogenic in animals (*30*). The converse argument—i.e., that chemicals carcinogenic to laboratory animals are carcinogenic to man—is now backed by considerable experimental evidence; but some of this evidence is indirect, and all of it must be qualified by consideration of the nature of the test and species, the specific incidence site, the route of administration, and the whole spectrum of processes involved in metabolism and excretion. The fact that well-known anomalies exist (aflatoxin B1 is carcinogenic in rats but not in adult mice; 2-naphthylamine is a potent bladder carcinogen in humans but weak or specific for other sites in rodents) should not be allowed to cloud the remarkable advances made within the last decade in our ability to extrapolate from animals to man.

In this regard, I was most impressed by a recent study by Gehring and associates (*31*) that used dose-response data on induction of angiosarcoma in rats exposed to vinyl chloride to estimate the risk for humans. The study predicted 10 hepatic angiosarcomas in an epidemiologic cohort of 9,677 workers—of which 5 have occurred. In view of the latent period for cancer development that still applies to a number of the workers, this is a powerful illustration of the accuracy of the animal model.

The limited resources and large numbers of chemicals involved necessarily restrict the number of animals that can be tested. Large doses must be employed to detect carcinogenic effects, and hence cancer risks at low doses have to be extrapolated. Since the work of Mantel and Bryan (*32*) in 1961, a number of mathematical techniques have been developed (*33,34*), with linear extrapolation currently holding sway as a means of projecting a worst-case hypothesis. In these types of experiments, even if there is no evidence of carcinogenicity, it is not possible to prove conclusively that such a risk does not exist (*35*). Moreover, extrapolation to low doses is fraught with imponderable factors; and the inappropriateness of equating physical radia-

Table 2. Twenty-six chemicals (and some related industrial processes) classed by the International Agency for Research on Cancer as being associated with human cancer.

Aflatoxins	Diethylstilbestrol
4-aminobiphenyl	Hematite (mining)
Arsenic compounds	Isopropyl oil
Asbestos	Melphalan
Auramine (manufacture of)	Mustard gas
Benzene	2-naphthylamine
Benzidine	Nickel (nickel refining)
Bis (chloromethyl) ether	N, N-Bis(2-chloroethyl)-2-naphthylamine
Cadmium oxide	Oxymetholone
Chloramphenicol	Phenacetin
Chromium (chromate-producing industries)	Phenytoin
	Soot, tars, and oils
Cyclophosphamide	Vinyl chloride

Source: L. Tomatis et al. (*29*).

tion damage with the cell reactions involved in chemical carcinogenesis, or of assuming that biological effects are proportional to dose regardless of the size of the dose or the rate of exposure, is being vigorously debated today. Nitrilotriacetic acid, for example, is considered carcinogenic at high doses because it denudes the organism of metal ions—a mechanism that does not pertain at low doses (*36*). Nevertheless, I would submit that these statistical techniques provide us with a tool for placing risk estimation within the total context of the problem involved.

The time, expense, and physical difficulties of animal tests have stimulated the search for short-term test methods able to detect carcinogens. The most promising approach to date relies on the correlation between mutagenesis and carcinogenesis. A number of mutagenicity assays have been developed—the best-known, most widely used, and most thoroughly validated being the *Salmonella* microsome assay developed by Bruce Ames and associates (*37*). None of these tests give incontrovertible proof of carcinogenicity, but the *Salmonella* assay has detected about 90 per cent of the carcinogens examined (*38,39*), as has an in vitro mammalian cell transformation assay (*39*). In combination, these two tests have detected virtually all carcinogens tested (99.2 per cent), although the incidence of false positives (8.8 per cent) was relatively high (*39*). Our own laboratories now employ a battery of short-term mutagenicity tests to provide information that helps us set priorities for additional research on a wide range of chemicals that are important constituents of common household products such as paints, solvent cleaners, and clothing fabrics.

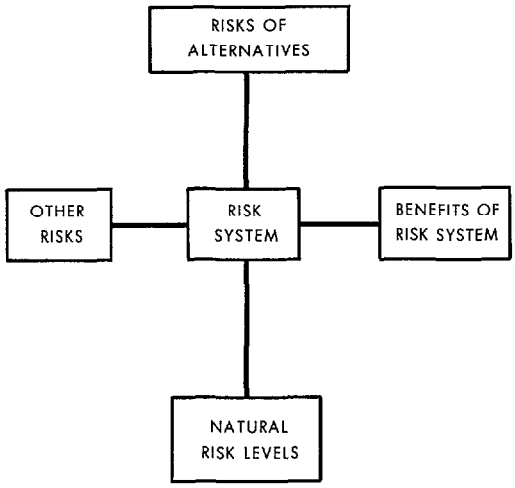
As the various factors influencing the relationship between a chemical's mutagenic potency and carcinogenic activity are better understood, it is likely that the assay procedures will be improved to increase the correlation. However, it is doubtful whether the short-term mutagenicity assay will ever replace the need for human epidemiology and animal cancer tests.

Risk Acceptability

I should like to turn now to the more general question of risk assessment for carcinogens, defining the elements of risk assessment as risk identification, risk estimation (a scientific determination made in as quantitative a manner as possible), and risk evaluation (judgment of acceptability) (*40*).

This last element, risk evaluation, is concerned with comparing risks against one another, weighing risks against benefits, and

Figure 1. A schematic approach to evaluation of a risk "system." Boxes on sides show the four types of comparisons involved.



Source: I. Burton and A.V. Whyte (*40*).

judging the risks' social acceptability. A particularly valuable risk evaluation technique is to compare the risk either with other risks or with presumed benefits. A schematic approach described by Burton and Whyte (*40*) is shown in Figure 1. This approach permits derivation of equations that will show levels of elevated risk (above natural risk levels), comparative risk (versus other risks), balanced risk (balanced against other risks), and risk-benefit (weighing the risk against benefits).

Elevated Risk

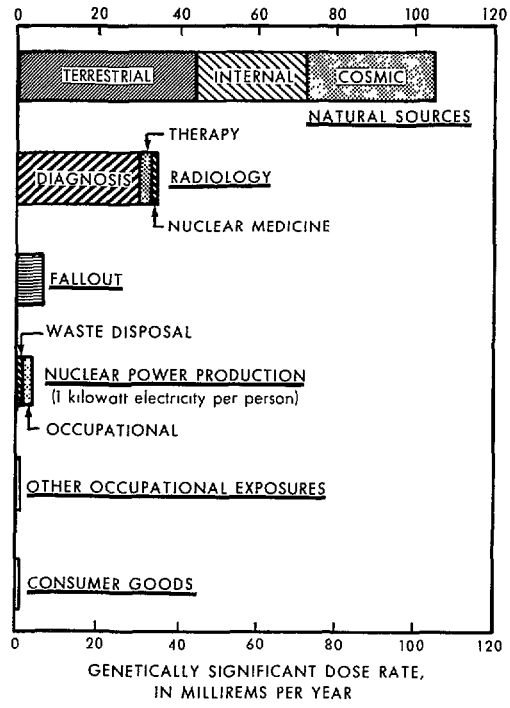
Elevated risk means risk compared with the risk posed by the natural background—the level of "noise" in the system. The contaminant may have been with us always—like mercury in fish or fluoride in drinking water—and its beneficial or adverse effects may have been accepted. Similarly, the natural background dose of ionizing radiation that we are subjected to is appreciable, being on the order of 100 millirems per year, with the cosmic radiation component being doubled for those who live at high altitudes.

Figure 2 shows the reported annual genetically significant dose-rate of ionizing radiation averaged through the whole population. One can see why proponents of nuclear power so often find the opposition inexplicable. The overall population exposure to radiation from the nuclear industry is only a small proportion of that received from natural sources.

Comparative Risk

Figure 2 also illustrates comparative risk, in that it shows the nuclear risk small compared to that received from X-rays and radiological therapy in medicine. That is, the

Figure 2. The genetically significant dose rate of ionizing radiation received annually by an average inhabitant.



Source: E.E. Pochin, from A.M. Aiken et al. (*41*).

Table 3. Comparison of the risks estimated for various activities.

Activity	Cause of risk	Deaths per million participants per year
Rock climbing[a]	Accidents	30-40
Coal mining (UK)[a]	All causes	300
Mining (USA)[a]	Accidents	1,000
Canadian population (1974)[b]	All cancers	1,500
Uranium mining (USA)[a]	Lung cancer	1,500
Asbestos Manufacturing (male smokers, UK)[a]	Lung cancer	2,300
Deep-sea fishing[a]	Accidents	2,800
Smoking 20 cigarettes per day[a]	Lung cancer	5,000

[a] *Source:* E. E. Pochin (*43*).
[b] *Source: Cancer Patterns in Canada, 1931-1974* (*5*).

medical and allied professions furnish the vast preponderance of our man-made dose of ionizing radiation—something that has caused much concern to health authorities (*42*).

A common criterion used to gauge comparative risk is the ultimate criterion of death. Pochin (*43*) provides an example of this approach (see Table 3), which is often used in comparing occupations or modes of transport. Cohen (*44*) has great fun applying this technique to the health risk posed by bladder cancer incurred from diet drinks containing saccharin: Failure to install a smoke alarm is as dangerous as ingesting three diet drinks per day; an average street crossing is about as dangerous as one diet drink. This is, of course, *reductio ad absurdum,* but the view of the ranking order can be salutary.

Balanced Risk

The risk posed by different alternatives—i.e., balanced risk—has been quantified for energy production. Inhaber (*45*) has calculated man-days lost and total deaths for a variety of energy systems (see Figure 3). As the figure indicates, with regard to total deaths (both public and occupational) and man-days lost per unit of net energy output (one megawatt-year), the energy generated by natural gas had the lowest overall risk associated with it, followed by nuclear energy and ocean thermal energy. Although these conclusions have been criticized, I submit that the analysis provides a logical approach when one has to weigh the risks from alternatives designed to yield the same end product, in this case energy.

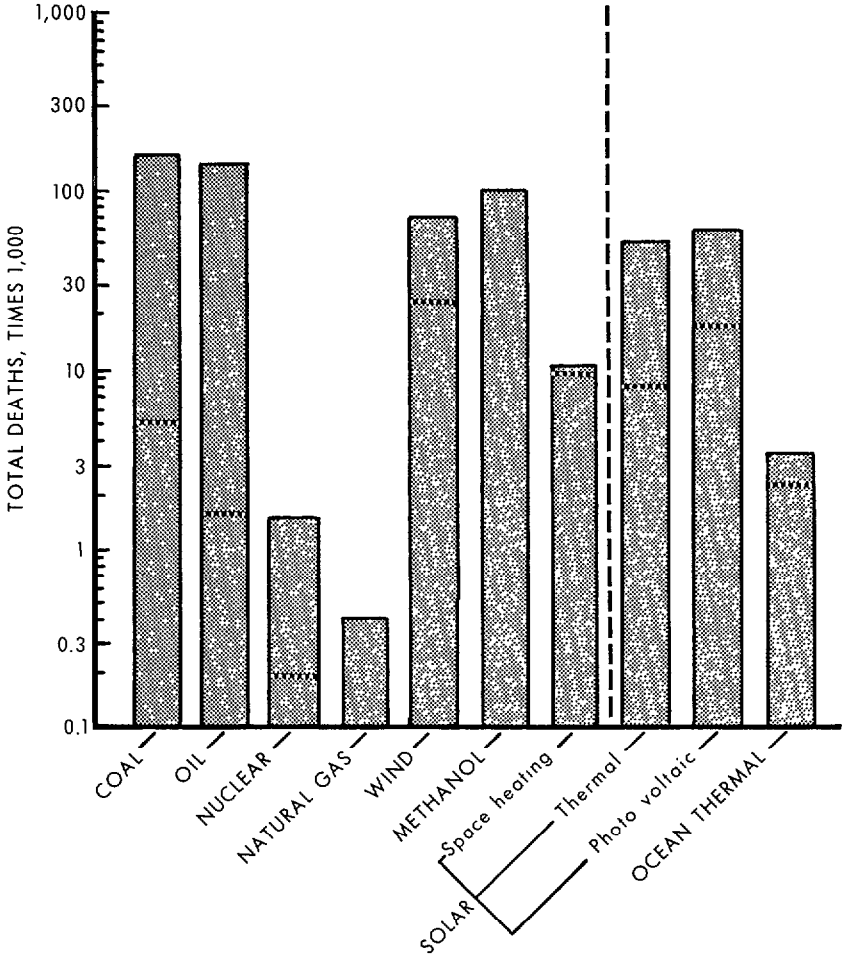
Choice of alternatives is at the heart of the risk assessment process. The knowledge that other fire retardants for textiles were available influenced the decision to ban Tris. When cyclamates were withdrawn from the market, saccharin was available for diet drinks. If chlorination of water supplies is replaced by ozonization, we need to ask: What is the toxicity of the reaction products and what is the microbial quality of the treated water? As the report on biological effects of ionizing radiation (*23*) noted:

> The public must be protected from radiation, but not to the extent that the degree of protection provided results in the substitution of a worse hazard for the radiation avoided.

Risk-Benefit

The fourth way to compare risks is to compare them with the benefits they bring. As patients, we accept the hazards of medicine, be they posed by drugs, surgery, or X-rays, because of their benefits. Pesticide risks to

Figure 3. The average number of deaths (times 1,000) expected to arise in producing one megawatt-year of energy by various methods. From H. Inhaber (*45*).



ecological systems can be weighed against increased food production. Chlorination of drinking water indisputably protects against a group of most unpleasant water-borne diseases.

Some of these benefits may commonly be accepted as outweighing the risks, but they also raise the basic problem of societal judgment. The seemingly objective techniques of cost-benefit analysis and decision analysis founder when they confront the reality of human values, aspirations, beliefs, and even whims. Although society implicitly costs human lives in many of its decisions, we cringe—and rightly so—from the abhorrent task of setting a monetary value on human life. In recent years this lesson has been learned the hard way in many countries, where the ultimate political decision on risk acceptability has overturned costly and protracted analyses proposing airport sites or nuclear reactors. There is a spirit of distrust of high technology abroad (*46*).

Over the last few years, great strides have been made in creating a rational framework for arriving at decisions. So long as we recog-

nize the limitations of our knowledge—realizing that some of our extrapolations (termed "trans-scientific" by Weinberg—*47*) may well exceed the practical applicability of the scientific method and that the regulatory decisions on environmental hazards from carcinogens are only as good as the political process that makes them—we will remain capable of coping with this extraordinary technological society we are creating.

SUMMARY

Our present "chemical" era has seen a dramatic rise in the use of new products, some of which pose serious health hazards and few of which have been adequately tested. Similarly, in recent years there has been a rise in both radiation-emitting devices and the development of nuclear energy. This article draws on Canadian experience in environmental management to illustrate means available to governments for assessing and controlling real or presumed risks posed by these developments.

One important type of assessment is evaluation of carcinogenic risk. In this field, rodent studies sometimes provide a basis for extrapolation of risks to man. For example, rodent studies have been used to set the maximum acceptable levels of chloroform and nitrilotriacetic acid in Canadian drinking water and to ban the use of saccharin, nitrosamines, and polychlorinated biphenyls. In addition, comparative studies of human populations can sometimes yield the information desired—as in assessing the dangers posed by water fluoridation, for example; and mutagenic test systems can sometimes prove useful—as they did in evaluating dangers posed by the flame retardant Tris.

Assessment of risks posed by ionizing radiation has a more secure foundation than assessment of risks posed by chemical carcinogens—because the biological hazards of radiation for human populations have been well demonstrated and the dose-effect relationships involved have been established. Hence these data, combined with sample survey data and test results, provide a good basis for calculating the risks posed by such things as X-ray equipment, nuclear reactor emissions, and radionuclides in water.

Besides evaluating such risks, of course, it is also necessary to weigh them against the benefits received, against other risks existing in the environment, and against risks posed by substitute products or devices.

Overall, great progress has been made recently in creating a rational basis for decisions. So long as we recognize that some of the extrapolations being made may well exceed the practical applicability of the scientific method, and that regulatory decisions are only as good as the political processes that make them, we will remain capable of coping with the extraordinary technological society we are creating.

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WHAT IS HEALTH IN THE CARIBBEAN CONTEXT?*

What is health in the Caribbean context? It is certainly not just the absence of disease. It is much more. It means that working people are fit and productive and able to acquire and use new skills, that school children are fit and able to benefit from their education and that their physical and mental development has not been permanently impaired by malnutrition in infancy. It means that every Caribbean family has the means either to produce or to buy the food that it needs. It means that the serious health hazards of the Caribbean environment and the resulting communicable diseases are brought under control. It means that mothers and children receive special care. It means that people are emotionally well-adjusted individually, in families and as communities, and free from dependence on alcohol or tobacco. It means that health care is delivered by well-trained, highly motivated health teams. It means that there is dynamic management of the health services. It means that people have determined for themselves the most important community health problems and are playing their part in solving them.

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