212

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Analyzing the Daily Risks of Life

by Richard Wilson

In our most trivial activities we incur risks. These hazards can be quantified and compared, but can they be eliminated from our lives?

Anthony Schultz

The world seems a very hazardous place. Every day the newspapers announce that some chemical has been found to be carcinogenic, or some catastrophic accident has occurred in some far-off place. This leads some of us to hanker after a simpler world where there are fewer risks to life. But does such a world really exist?

If we look back at the world of a century ago, we find that expectation of life was 50 years; now it is 70 years. Therefore the sum of all the risks to which we are now exposed must be less than it was. We find that many of the large risks of the last century have been eliminated, leaving us conscious of a myriad of small risks, most of which have always existed.

The moment I climb out of bed I start taking risks. As I drowsily turn on the light I feel a slight tingle; my house is old with old wiring and there is a small risk of electrocution. Every year 500 people are electrocuted in the United States. I take a shower, and as I reach for the soap, I wonder about the many chemicals it contains. Are they all good for the skin, as the advertisements claim? My clothes have been cleaned with the best bleaching detergent. Most bleaching agents contain a chemical that fluoresces slightly in the sunlight to enhance the whiteness. Does this make bleaches carcinogenic?

I ponder this risk as I walk down to breakfast, taking care not to fall upon the stairs. Falls kill 16,000 people per year — mostly in domestic accidents. Shall I drink coffee or tea with my breakfast? Both contain caffeine, a well-known stimulant which may be carcinogenic. I have a sweet tooth; do I use sugar which makes me fat and gives me heart disease, or saccharin which we now know causes cancer? It is better to abstain.

After breakfast I make a sandwich for lunch. My son likes peanut butter. But improperly stored peanuts can develop a mold which produces a potent carcinogen — aflatoxin. In Africa and Southeast Asia, where aflatoxin appears more frequently, it has been blamed for numerous cases of liver cancer. In our (less natural) society storage facilities are better, so the risk is less — but it is not zero.

I prefer meat. But Americans, like other prosperous people, eat too much meat. It is not certain, but a meat-heavy diet probably contributes to cancer of the colon.

I live seven miles from work and can commute by car, by bicycle, or by bus. Which has the lowest risk? To travel by bicycle would keep my weight down, and bicycle riding does not cause pollution — but statistics show that it is more likely to involve me in an accident. And since a bicyclist is unprotected, fatal accidents are also frequent on a bicycle. A car would be safer, but a bus is safest. I am happy that I no longer have to choose between a horse and a canoe; both are more dangerous (per mile) than a bicycle.

As I approach Boston, I see the urban haze caused by air pollution. There are toxic parts of air pollution which are not visible, as well. The risk to life caused by air pollution is high. Asthma victims have known this for a long time and fled the industrialized eastern United States for the purer air of the West. A press release from a government laboratory states that air pollution kills 20,000 people a year in the eastern United States. Air pollution, though still bad, has been reduced in most cities.

I remember the pea-soup London fogs of my youth caused by burning soft coal, where I could not see ahead ten feet; and the infamous week in December of 1952 where 3,000 people died from air pollution in four days.

I go to a committee meeting in a small, unventilated room. Although I don't smoke tobacco, half of the committee does, and I am exposed to the poison which causes 40 per cent of all cancers and kills 15 per cent of all Americans. Even though I breathe less tobacco smoke than my smoking colleagues, I often get a headache. One of my friends, who is more allergic than I, wears goggles at work.

At mid-morning I take a drink of water. The water tastes of chlorine, showing that the city's sanitation engineers use chlorine to kill microbes in the water. By such methods the country has nearly wiped out cholera and typhus. But the chlorine reacts with organic matter in the water to produce many known carcinogens. One of them, chloroform, is produced in a concentration of 100 parts per billion; enough to present a health hazard.

My office walls are brick and cinder block. Both contain radioactive materials, and radiation can increase my risk of cancer. One of these radioactive materials, radon, is a gas which is not chemically active. It is released by the brick and I can breathe it, which accentuates the hazard. I could prevent the release of this radioactive gas by painting the walls with thick epoxy paint to seal them, but that would introduce another risk. As the epoxy paint cures, it emits gaseous chemicals which are themslves carcinogenic. Which is worse?

Radiation enters all of my life. State law requires that I have a regular chest x-ray to see whether I have tuberculosis and may convey that dread disease to my students. But this adds to my risk of cancer from radiation. Is it correct for society to demand that I accept this risk, even to protect the rest of society from a greater one?

I frequently travel to meetings. Should I go by car, bus, train, or airplane? Thirty years ago the statistics were clear; the airplane was far more dangerous than all the others, since many airplanes crashed. Now, for journeys of 1,000 miles or more, air travel is the safest. But airplane travel causes an often-ignored radiation hazard, exposure to cosmic radiation from outer space. Airplanes fly at 30,000 feet, and at that altitude cosmic radiation exposure is 40 times what it is at sea level. Even a vacation trip to the high altitudes of Colorado and Wyoming can increase cosmic ray exposure. Sunlight at these altitudes, and excessive exposure even at sea level, showers us with ultraviolet light, which causes skin cancer.

These are personal concerns, and it might be argued that they are of no concern to anyone else, since I can avoid some of them. But in doing so I may well cause problems for others in society.

In the bad old days of my childhood we burnt coal in the house. If I heat my house by electricity I will not personally pollute the air with the products of fossil fuel burning; but these may still be produced at the power plant. One hopes the electric company is more careful about these pollutants than my parents used to be.

Whether I burn the coal myself or let the electric utility company do so, coal miners must still go underground. Anyone who has read *How Green Is My Valley* knows that 100 years ago coal mining was one of the most dangerous occupations. Even though mine safety has improved, it still has hazards: 156 out of every 100,000 miners were killed in accidents in 1972 in the United States. Yet accidents are not the worst hazard of coal mining: 800 miners yearly contract the dread black lung disease — coal workers' pneumoconiosis — from inhaling coal dust. One quarter of all American miners working in 1977 will probably contract this disease during their lifetimes. As an environmentalist I hate to see the beautiful western states laid bare by strip mining; but do I have a right to allow miners to die by refusing to let them work above ground?

Our society has a quirk which is fostered by our news media. We are far more concerned with infrequent large accidents than with numerous small accidents which, in total, cause many more deaths.

Congress was prompted into insisting on better mine ventilation to prevent black lung disease only after a much smaller number were killed in a single accident. A single accident of a school bus receives more newspaper coverage than the thousands of children killed yearly in automobile accidents.

This obsession with large accidents is getting worse. We are apprehensive at the *thought* of a large accident in a nuclear power plant, although none has happened so far, and experts are optimistic that none will ever happen. Nor is the fear unique to nuclear power. We bring to the United States considerable quantities of liquefied natural gas (LNG) and worry about the possibility of the ship leaking and blowing up. LNG *has* caused problems in the past; 30 years ago, an LNG tank, one-tenth the size of modern ones, collapsed and killed 133 people. We now know why this tank collapsed, and new tanks will not collapse in the same way since the metal from which the tanks are made has been changed.

Comparing the Risks We Face

There are those who would try to eliminate all known risks and would try to force this by law. This sounds plausible, but it creates an incentive for ignorance, not an incentive for safety. Under this procedure if we do not know whether something is risky and close our eyes to the possibility of risk, no one will bother us. On the other hand, if we look carefully and find there is a risk — even though it is small — some regulatory agency may stop us.

It would be a better policy to try to measure our risks quantitatively, and to give an *upper limit* on a risk when there is uncertainty. Then we could compare risks and decide which to accept or reject. I suspect most of us would decide to reduce the largest risks first.

To compare risks we must calculate them. As I prepared the table on page 45, I realized that an increased risk of death of one in a million is often seen as acceptable, but people instinctively think about large risks. I list here several actions which increase the chance of death in any year by one in a million.

Of course, if the risk of death in one year is increased, the risk of dying from another cause in a later year is decreased. The average expectation of life is shortened. Accidents often occur early in life, and life may be shortened 30 years by a typical accident. Cancer, black lung, and bronchitis kill later in life, and life is shortened only about 15 years. Therefore, a risk of 0.000001 (or 10^{-6}) shortens life on the

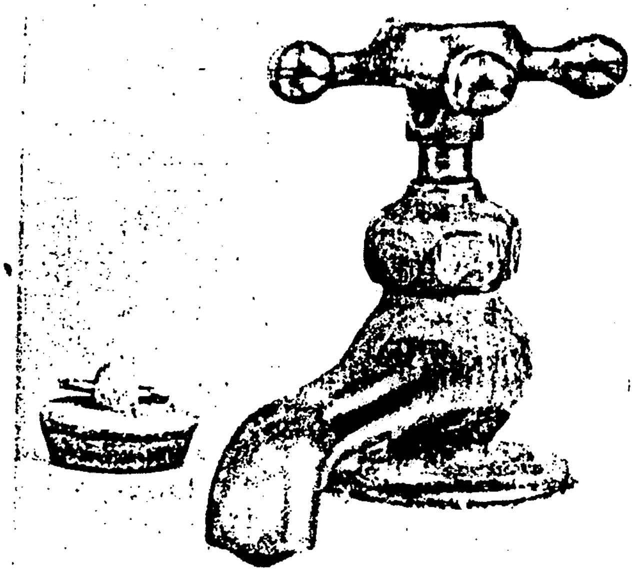

Photo: Fredrik D. Bodin, Stock, Boston

"The moment I climb out of bed I start taking risks . . . I take a drink of water . . . the chlorine reacts with organic matter to produce many known carcinogens."

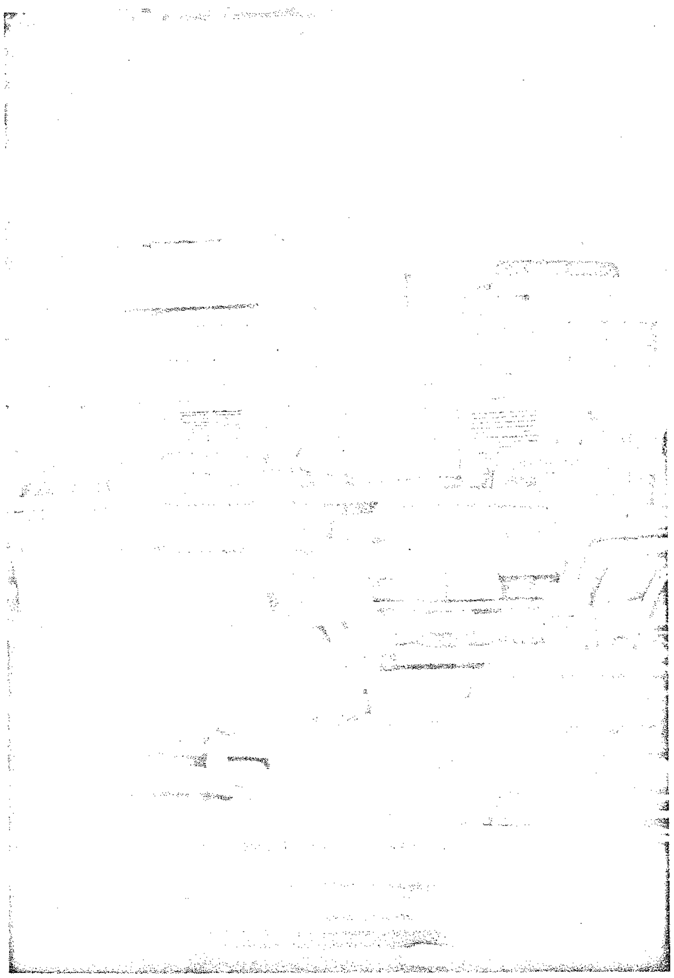

Photo: Michael Dobo, Stock, Boston

"As I approach Boston, I see the urban haze . . . Air pollution kills 20,000 people a year in the eastern U.S."

average by 30×10^{-6} years, or 15 minutes if it is an accident risk, 8 minutes if it is a risk of fatal illness.

I illustrate what this table means by calculating examples. In the United States 627 billion cigarettes were made in 1975. This is enough for 3,000 per person (including children), or a little less than half a pack a day. It is estimated that 15 per cent of all Americans (30 per cent of all smokers) die from lung or other cancers or heart disease due to smoking. We describe this as an average lifetime risk of 0.15. Dividing by the 70-year lifetime gives a yearly risk of 0.002 or 2×10^{-3}; dividing again by 3,000 gives a risk per cigarette of 0.7×10^{-6}. It is amusing to note that smoking a cigarette takes ten minutes and reduces the expectation of life by five minutes.

Human affairs are much more random than we like to think. One boy playing on a street can be killed by a passing car while his playmates are unharmed. All were equally at risk before the accident, but only one died. Similarly, one out of three lifetime smokers dies of cancer or heart disease because of the habit; the rest are unaffected and die of other causes. Moreover, those that die of cancer and heart disease do so at different ages. We have no way of telling which particular smokers will die of cancer, so we say that all are equally at risk.

It has been shown that those who smoke 40 cigarettes a day are ten times more likely to develop cancer as those who smoke four cigarettes a day. Perhaps there is a level of consumption where the risk becomes zero, but we cannot measure that low. It is easier to assume that every cigarette contributes the same amount to the total risk.

Brookhaven National Laboratory recently estimated that 20,000 Americans die every year from air pollution east of the Mississippi. This is partly due to sulphur emitted from burning coal and oil, and measurements suggest that the sulphate particulates spread themselves roughly uniformly over town and country. About 100 million Americans are exposed to this dirty air, so the average risk is 20,000/100,000,000 every year or 2×10^{-4} or 0.0002. Two days in New York City give a risk smaller by 2/365 or about 10^{-6} (one in a million).

Recent aircraft accident statistics tell us that aircraft in the United States carry passengers 100 billion passenger-miles every year and only about 100 people a year are killed in airplane crashes. This gives a risk of one in a million for one thousand miles of flight.

Professor Norman G. Rasmussen of M.I.T. made a study of nuclear reactor accident probabilities for the Nuclear Regulatory Commission. He concluded that a reactor accident involving loss of life is very unlikely. The chance of an accident with more than 1,000 deaths is less than one in a 100 million per year of operation for each reactor. Most of these would be among the 20,000 or so people living within five miles of the reactor. So the probability of an individual living near a reactor being killed in a large accident is 1/2000 million. But those close by might also suffer in smaller accidents which, even though still unlikely, are more probable, leading to a risk of 1/50 million for persons living close to reactors.

Other more dangerous radiation hazards, such as natural radioactivity in brick, cosmic radiation, and diagnostic x-rays, are calculated by measuring the radiation dose and dividing it by the measured effect of large doses. The risks of these commonly accepted radiation hazards are far greater than those estimated for nuclear power.

I find these comparisons help me evaluate risks, and I imagine that they may help others do so, as well. But the most important use of these comparisons must be to help the decisions we make, as a nation, to improve our health and reduce our accident rate.

Taxing a Risk

Economists are fond of using taxation to control human affairs. Indeed, the invention of money by Croesus made a great simplification in the relationships in society. One suggestion, then, is to tax anyone who introduces a risk into society. This tax could pay for medical care, for compensating society for the loss of services, etc. The question arises: How much should the tax be? I suggest, as a basis for discussion, that this tax be at the rate of $1 million for every life that is lost by this extra risk, or one dollar for a risk of one in a million. Conversely, anyone that can save a life by an expenditure of $1 million must be encouraged to do so.

For example, the manufacturer who panders to the bad habit of cigarette smoking would pay an increased tax of 70 cents *per cigarette*. This is more than enough to pay the societal cost of cigarette smoking (hospital costs, fire hazards, reduced working time), which is variously estimated at from $1 to $2 per pack. Other taxes — five cents per diet soda — are less dramatic and might have to be accompanied by a tax of five cents on other sodas as well to prevent a switch to sugar.

Risks which increase chance of death by 0.000001*

Smoking 1.4 cigarettes	Cancer, heart disease
Drinking 1/2 liter of wine	Cirrhosis of the liver
Spending 1 hour in a coal mine	Black lung disease
Spending 3 hours in a coal mine	Accident
Living 2 days in New York or Boston	Air pollution
Travelling 6 minutes by canoe	Accident
Travelling 10 miles by bicycle	Accident
Travelling 300 miles by car	Accident
Flying 1000 miles by jet	Accident
Flying 6000 miles by jet	Cancer caused by cosmic radiation
Living 2 months in Denver on vacation from N.Y.	Cancer caused by cosmic radiation
Living 2 months in average stone or brick building	Cancer caused by natural radioactivity
One chest x-ray taken in a good hospital	Cancer caused by radiation
Living 2 months with a cigarette smoker	Cancer, heart disease
Eating 40 tablespoons of peanut butter	Liver cancer caused by aflatoxin B
Drinking Miami drinking water for 1 year	Cancer caused by chloroform
Drinking 30 12 oz. cans of diet soda	Cancer caused by saccharin
Living 5 years at site boundary of a typical nuclear power plant in the open	Cancer caused by radiation
Drinking 1000 24 oz. soft drinks from recently banned plastic bottles	Cancer from acrylonitrile monomer
Living 20 years near PVC plant	Cancer caused by vinyl chloride (1976 standard)
Living 150 years within 20 miles of a nuclear power plant	Cancer caused by radiation
Eating 100 charcoal broiled steaks	Cancer from benzopyrene
Risk of accident by living within 5 miles of a nuclear reactor for 50 years	Cancer caused by radiation

*(1 part in 1 million)

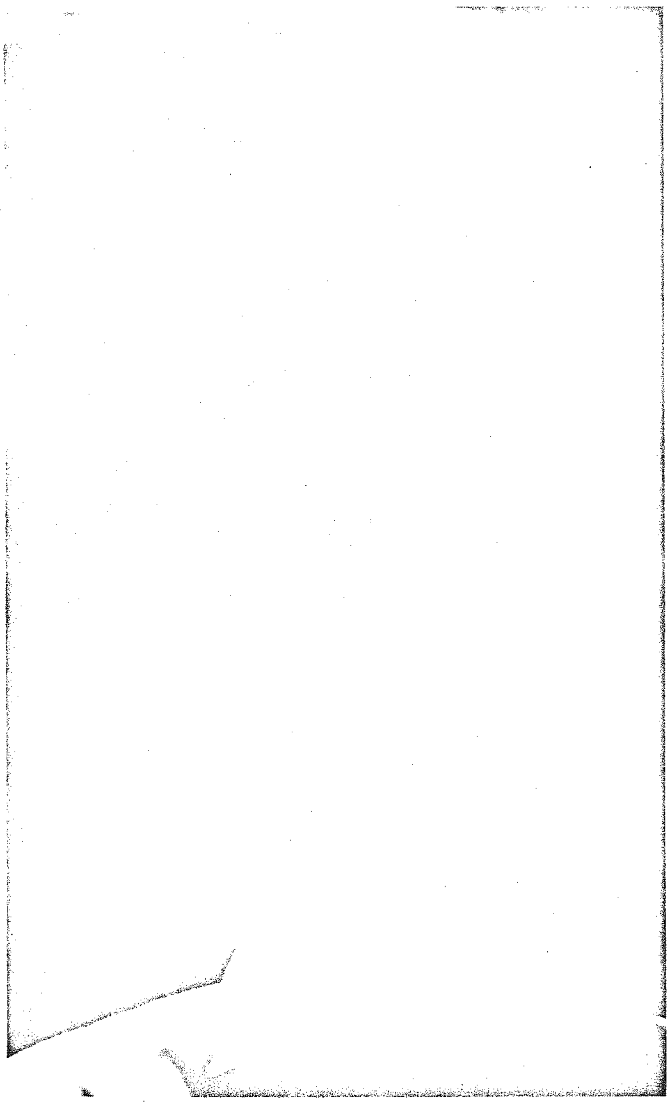

Photo: Peter Menzel, Stock, Boston

"I go to a committee meeting in a small, unventilated room. Although I don't smoke tobacco . . . I am exposed to the poison which causes 40 per cent of all cancers and kills 15 per cent of all Americans."

These taxes might be earmarked to pay for risk reductions such as converting an existing sanitation system to using ozone instead of chlorine for sanitation, to avoid the production of chloroform.

Whether we quantify these risks or not, we must and do constantly make decisions about them. We do this as individuals, and our politicians make these decisions for us on a larger scale. What we are not doing, and need to do, is comparing the risks of various activities and then reducing the largest risks — which may not be the obvious ones.

After calculating these risks all day, I go home. I am still faced with decisions about risks. If I cook a meal in the microwave oven and the door doesn't fit tightly, I will be exposed to microwaves. It has recently been claimed that microwaves, even at low concentrations, give people nervous problems. Or I can use the gas stove, but the burning gas can fill my kitchen with both noxious carbon monoxide and nitrogen oxides.

Just as I go to bed I take a glass of beer. Alcohol causes cirrhosis of the liver and has been associated with oral and other cancers. However, the relaxing effect of the beer will reduce my stresses and permit a good night's sleep. This will prolong my life and is worth the risk.

The beer is in a green glass bottle which contains chromium, a small amount of which enters the beer. Chromium is a known carcinogen when ingested in moderate quantities, but it must not be avoided altogether because it is essential to life in small concentrations. How much chromium should I take to minimize the risk? Is the amount in the beer too much? Should I drink the beer from a plastic bottle? A plastic bottle suitable for beer has just been banned because a trace of the chemical from which the plastic was made could dissolve in the contents, and there is a suspicion that the chemical is carcinogenic.

I ponder this decision as I put on my pajamas. Are the pajamas inflammable? There is always a small risk of a fire starting while I am in bed. Is the risk of being burnt in a fire greater or smaller than the risk of cancer caused by a flame retardant such as TRIS?

I remember the truism "more people die in bed than anywhere else," so at least I'm in the right place.

Richard Wilson is professor of physics at Harvard University. Educated at Christ Church, Oxford, he received his Ph.D. in 1950. For many years he has been concerned with energy and the environment. He served on the National Science Foundation Physics Advisory Panel, as a consultant on nuclear power to the Attorney General's Office of the state of Maine, and as a consultant to the Nuclear Regulatory Commission. He is Assistant Editor of *Annals of Physics*.