BENEFITS AND RISKS OF CHEMICALS IN THE ENVIRONMENT

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ABSTRACT

All chemicals known to man, both natural and synthetic, are present in the environment. Many are essential to life. All are toxic in high enough doses. Some are mutagenic, some are carcinogenic, some are teratogenic and some have other toxic effects. Each has a concentration below which it does no harm. b.s.

Although total elimination of chemicals from our environment is impossible, it is vital to minimize the concentration of harmful chemicals and therefore to minimize the risk. The benefits of carefully controlled use of chemicals for food production, for weed control, for insect control, for prevention and cure of disease, for maintenance of health and for the enrichment of human life must be weighed against the risks involved.

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INTRODUCTION

There is a great deal of concern today about the effects of chemicals in our environment on human health. Our newspapers are full of scary headlines and worrisome articles about the harmful chemicals in water, air, soil and food. Is this scare campaign justified? Are there seriously hazardous chemicals in the environment?

Yes, there are many hazardous chemicals. A few chemicals are very serious hazards. All chemicals are toxic if ingested in large enough doses, but each has a concentration below which it is not harmful to human health and life. It is a question of determining this concentration for each substance.

ESSENTIAL CHEMICALS

Many chemicals are absolutely necessary for you and me to live. The most essential chemical is water, without which we, and most other living things, would not exist. We are over 80% water. We can live without food for 50 to 65 days, as clearly demonstrated by the ten members of the IRA who starved themselves to death in prison year. But we die within a week if we are deprived of water!

Another essential chemical for us, and for most, but not all, other animals and plants, is oxygen, which constitutes about 21% of our atmospheric environment. We need to breathe it in, absorb it into our blood through our lungs, and use it to oxidize glucose to carbon dioxide and water to provide energy. We need a constant supply of energy, not only to keep our bodies warm and to make our muscles work, but also to keep our brains functioning, the central controllers of our living systems.

Nitrogen is also an essential chemical. It is an inert gas needed to dilute the oxygen in the atmosphere. Pure oxygen is very important at certain times, but our metabolism would normally function too fast and exhaust our bodies if the normal partial pressure of oxygen were not maintained. Sodium chloride, common salt, is a chemical we must have, along with potassium ions to maintain the balanced composition of our blood.

Many other minerals must be present in our food or water, or supplied in some other way to maintain life: calcium, magnesium, iron, zinc, copper, cobalt, phosphorus, chlorine, iodine and fluorine.

Then there are all the "vitamins", substances which our bodies must have to maintain health, but which we cannot synthesise ourselves. These essential chemicals must be obtained from our diet or as supplemental drugs. Many diseases result from deficiences in the intake of these chemicals. They were given letters of the alphabet as they were identified, and then subscript numbers when it was discovered that several chemicals were involved in some classes of vitamins. Lack of vitamin A affects growth of children, diminishes acuity of vision, and disturbs the integrity of epithelial tissues. Deficiency in vitamine B1, a chemical called thiamine, produces beriberi, neuritis and cardiac disease. Vitamin B2, riboflavin, promotes growth and general health. Lack of vitamin B12, cyanocobalamin, produces pernicious anemia. Vitamin C, ascorbic acid prevents scurvy, and promotes health in a variety of ways. The list of other vitamins we must have to maintain health is quite long.

Proteins are components of all living tissues. We can synthesise them in our bodies as we need them for growth, repair and replacement, provided we ingest the necessary raw materials. Proteins are made of long chains of 26 amino acids, containing different proportions of these arranged in an almost infinite number of ways. Some of these amino acids can be synthesised in our bodies from others, but ten of them, called "essential amino acids", must be obtained ultimately from plant proteins which contain them. These ten substances must therefore be included in the long list of chemicals essential for human life.

Another essential chemical is glucose on which we depend for our energy, but we get this from carbohydrates and our bodies can sythesise it from protein and from fat, so we never run out of glucose unless we starve to death!

TOXICITY

Although so many chemicals are required in limited amounts for us to exist, nearly five hundred years ago Paracelsus said: "All substances are poisons; there is none which is not a poison. The right dose differentiates a poison and a remedy."

Every chemical is toxic if administered in sufficient dose, even water. "Acute toxicity" is expressed for each chemical as LD50, the lethal dose which will cause half the test animals to die. For water the LD50 is about 500 grams per kilogram of body weight. It would be difficult to drink half our body weight in water, but it has been done by force as a means of torture. The LD50 for salt, sodium chloride, is about 4 grams per kilogram; for 2,4-D about 1 gram per kilogram. For sugar, sucrose, it is about 70 grams per kilogram; for glucose about 25 grams per kilogram. Many pesticides, like Picloram, have lower acute toxicity than salt, and some are no more toxic than glucose! I will discuss very toxic chemicals later.

LIFE EXPECTANCY

When I was born, in 1912, life expectancy at birth in North America was 47 years; a child born today, has a life expectancy of 70 years. Advances in chemistry account for much of this change: improved nutrition; the discovery of vitamins; mass production of chemical fertilizers; development of chemical herbicides to destroy weeds and increase the yields of food crops; creation of disease resistant varieties of food plants; breeding healthier and more efficient food animals; improved sanitation; chlorination for disinfection of water and sewage; discovery and large scale production of penicillin and other antibiotics to combat bacterial infections; discovery and production of insulin to combat diabetes; development of vaccines for immunization against smallpox, poliomyelitis, yellow fever and other viral infections; production of chemical insecticides to destroy disease carrying and crop destroying insects.

BENEFITS AND RISKS

Every advance in chemistry is accompanied by benefits and by risks. We take so many of the benefits of chemistry for granted today, benefits which often represented a revolutionary quantum jump in human welfare, enhancing our ability to feed the human race, to provide shelter, clothing and other human comforts, to improve health, to increase our life expectancy, and to inhibit fertility to control the human population to that which the physical resources of the earth can sustain. Now we tend to overlook the benefits, and emphasize the risks. We must make the public aware of the benefits and the risks involved in these great advances in chemistry, and we must weigh the risks against the benefits.

LIFE SAVING CHEMICALS

What man-made chemicals have saved the most human suffering and saved the most human lives?

Among the top ones I would list ammonia, chlorine, calcium superphosphate, DDT, 2,4-D, 2,4,5-T, triazine herbicides, penicillin and other antibiotics, but the list of other chemicals which have improved human health and welfare is very long indeed.

FIXATION OF NITROGEN

The greatest contibution of chemistry to human welfare was Haber's process for fixing atmospheric nitrogen, invented in 1911, the year before I was born. By combining nitrogen from the atmosphere with hydrogen under high temperature and pressure, ammonia was produced on an industrial scale. Today, 1000 tons per day ammonia plants are common, providing liquid ammonia, ammonium sulphate, ammonium nitrate and ammonium phosphate as fertilizers to increase manyfold the productive capacity of the arable land of the earth, without which the current population of the world could not be fed.

Like all the other great chemical advances, this one also has its costs. The fixation of nitrogen led to the mass production of nitric acid, an essential raw material for making nitrocellulose for rifle bullets, TNT and other explosives for artillery shells, without which large scale war would be immpossible, nuclear weapons notwithstanding.

CHLORINE

Chlorine is simultaneously a great blessing to humanity and a significant threat. Chlorine began to be used for disinfection of water the year before I was born. Thus in my lifetime chlorine alone has saved more lives and more human suffering than any other chemical, through nearly eliminating typhoid and other water-borne diseases.

Unfortunately chlorine in water reacts with substances which contain methyl carbonyl groups to produce chloroform, which has produced cancer in animals. Mutagenicity has recently been found after chlorination of municipal water supplies in both Canada and United States.

In my laboratory we have found that all phenols, including those in lignin and humic acids found in water, on treatment with chlorine in dilute water solution, produce chlorinated phenols, which are highly toxic, and other chemicals which are mutagenic, which means they change the genetic code, the DNA, deoxyribonucleic acid. It is good that most such mutagens are unstable in neutral water, but some of them are stable and persistent.

Fortunately we have found a chemical which can eliminate these problems. Replacement of chlorine with chlorine dioxide avoids the formation of mutagens and chloroform in the bleaching of pulp and in the disinfection of water and sewage. I am very happy to have been a pioneer in the mid-forties in the manufacture of chlorine dioxide and in its use for bleaching pulp. Today more than half a million tons of chlorine dioxide is produced per year world-wide, and its use is increasing rapidly.

DDT

Malaria, for thousands of years the number one killer of human beings, was finally brought under control after World War II by DDT. So was typhus, a disease communicated by body lice, which previously killed more people than died in battle. But today, instead of hearing about the millions of human lives that have been saved by DDT over the past forty years, we are told about the damage it does to our natural environment, which is comparatively minor. Where are our relative values; where is our comparison of benefits and risks?

I would like to quote from a recent Canadian book on "The Use and Significance of Pesticides in the Environment" by Professors McEwen and Stephenson of the University of Guelph.

"The insecticidal properties of DDT were recognized by Muller in 1939, who received a Nobel Prize in 1948 for the discovery of DDT and its effectiveness against a wide variety of arthropods. Its firt major use was in Naples in 1943 where it eliminated an outbreak of typhus that had been a factor in the outcome of many military campaigns. DDT was used against insect carriers of important world diseases such as plague, yellow fever, and most importantly, malaria. Residual treatment of homes in malarious climates resulted in the eradication of malaria in 37 countries by 1972, and a drastic reduction of cases in an additional 80 countries, bringing an heretofor undreamed of malaria relief to 1.5 billion people. In India alone, the indicidence of malaria decreased from 100 million cases annually in 1933-1935 to 150,000 cases in 1966, and death from this cause was decreased from 3/4 million to 1500 per year".

"It is difficult for the majority of people in North America to appreciate the need for pesticides to protect food and fibre. Since the dawning of the modern age of pesticides in the late 1940's, food and fibre have been protected so well that products showing extensive damage from pests have not appeared in our supermarkets. People under the age of 50 have never done their grocery shopping in an era when products infested with insects or rotting from plant diseases found their way into most shopping baskets.

"We must all "recognize that pesticides are an important and necessary part of modern technology that ensures our food supply". We must "ensure that the benefits are multipied and the risks decreased".

"The effectiveness of DDT in forestry was no less spectacular. Forest pests like the gypsy moth, the tussock moth, the hemlock looper, and the spruce budworm, against which man had been comparatively helpless, now became amenable to treatment using airplanes."

"DDT was not alone. The chemists now had a nucleus around which to build, and in quick succession, a number of compounds structurally related to DDT appeared. In addition, the cyclodienes were synthesized, and these did for soil insects what DDT had done for foliar pests. During the next twenty years these insecticides were joined by the organophosphates, the carbamates, and more recently new compounds of various design attempting to mimic the naturally occurring insect hormones but used in a way to disrupt normal life processes."

"The rapid developments in insecticides were paralleled by new discoveries of compounds effective for plant disease and weed control. The pioneering discoveries of 2,4-D and atrazine provided selective herbicides that contributed immeasurably to mechanization of crop production and efficiency of labour inputs."

VERY TOXIC SUBSTANCES

The most toxic substance known to man is botulism toxin, produced by a microbe, clostridium botulinus, which forms very stable spores, which are very widespread, but which can only grow and produce toxin in the absence of air. The protein-like toxin is so toxic that the amount on the point of a lead pencil can kill a thousand people. Fortunately, heat rapidly denatures the toxin, and so does any acid. Only if the infected food is eaten uncooked will people be poisoned by it. Apparently no one lives long enough to develop an antibody for this very toxic protein. There are about 50 outbreaks of botulism poisoning per year in the United States.

The second most toxic substance known is also a natural one, Aflatoxin B1, which is produced by a fungus, Aspergillus flavus, which grows on peanuts, corn and other crops. It destroys the liver and causes cancer in very minute quantities, but still very large compared with what can now be measured analytically.

The extreme precautions taken by Canada Packers (and other producers) to prevent aflatoxins from getting into peanut butter are exemplary. First, they only purchase peanuts certified by the U.S.government to contain less than 25 parts per billion of aflatoxins. On arrival, each shipment of peanuts is sampled and tested here. If it is found to contain more than 25 ppb aflatoxins, our federal government is called in to check the sampling method. If it is satisfied, the samples are sent to the U.S.

government to check, and if they find over 25 ppb, the whole shipment is returned and the money is refunded.

Then after roasting, each half of each one of millions of peanuts is examined in a special electronic colour sorting machine, which automatically rejects any dark coloured piece, which might indicate fungus attack. Then after the peanut butter is made each batch is analytically tested and any containing more than 10 parts per billion of aflatoxins is rejected. One part per billion is equal to a very dry Martini containing only one ounce of vermouth in 630 ten thousand gallon tank cars of gin! Incidentally, there have only been a little over a billion minutes of time since the birth of Christ!

The third most toxic substance is one produced by man, 2,3,7,8-tetrachlorodibenzo-p-dioxin, 2,3,7,8-TCDD for short. It is not made purposely; it is a trace impurity in 2,4,5-T, a very important herbicide. Today, after its high toxicity was discovered, the concentration of 2,3,7,8-TCDD is maintained below 0.1 parts per million in 2,4,5-T, which is so low that it is not regarded as a significant hazard in normal use. Our federal government has decided that renewed restrictions on its use are not justified, but some provincial governments have imposed their own restrictions.

CHEMICAL ANALYSIS

How can we determine such low concentrations of chemicals in anything? When I was a student, analysis using test tubes, beakers and burettes was laborious and time consuming, and the normal sensitivity was limited to 1 part per thousand. Gravimetric analysis with an extremely sensitive balance could increase sensitivity to 1 part in 10,000, but that was near the limit. Separation and identification of substances in very complex mixtures was a monumental task, which took several months of work.

Today analytical chemistry has advanced so far that in my laboratory our present gas chromatograph can separate a multitude of chemical compounds very quickly. It can detect one femtogram of Mirex, 10^{-15} grams!

Much of our concern about chemical pollution, and particularly toxicity and mutagenicity, has only developed very recently, and is a direct result of the extreme sensitivity of our modern methods of analysis. Previously we have been much more concerned about disease producing microoganisms, and quite properly so, because they can multiply in our bodies and kill us relatively quickly. Only in the last decade or two, through these enormous advances in instrumental chemical analysis, has it become possible to detect, to identify and to determine quantitatively the minute concentrations of toxic chemicals in our food and in our potable water supplies, and this has created alarm.

Very few people understand that all of us can ingest some quantity of any non-living chemical without harm. If this were not so we would all be dead long ago! Because Avogardro's number, as everybody who has studied any chemistry would know, is the number of molecules in a gram molecular weight of any chemical. It is so extremely large, 6^{23} molecules per gram mole, it can be expected that at least a few molecules of every stable chemical will be present in the water we drink and the air we breathe and the food we eat!

I like to drive this point home to students by pointing out that 18 grams of water, less than 2/3 of an ounce, contains six times ten to the twenty third molecules. As water is recycled by evaporation to the atmosphere and condensed as rain or snow, it is statistically probable, perhaps even statistically certain, that every glass of water we drink contains a few molecules of water that have passed through the body of Christ, or any other person who ever lived!

Each chemical has a concentration above which it will be acutely toxic, its LD50, and another very much smaller concentration which may damage our health in some way if we ingest it for a long time. It is important that everyone understand that at well below the second concentration we can drink the water, breathe the air and eat the food indefinitely without harm. However, it is very difficult to find that limit, because we cannot use human test animals.

DIOXINS

There have been alarming headlines about "dioxin" in Lake Ontario, and the articles on which they have been based have been very misleading. They use the word "dioxin" as if there was only one such substance. They always mean chlorinated dioxins, of which there are 75 different individual chemicals, some of which have very low toxicity and some have rather high toxicity, and of which only one, 2,3,7,8-tetrachlorodibenzo-p-dioxin, 2,3,7,8-TCDD for short, is the extremely toxic substance we discussed. It was reported recently that fish have been caught at the mouth of the Credit river containing an average of 27 parts per trillion of 2,3,7,8-TCDD, while the recommended limit is 20 ppt. The alarm is completely unjustified.

There are several factors which everyone must understand. First, how small a quantity a part per trillion really is. In length, it is the width of a human hair compared with the distance around the world. In time it is 1 second in 320 centuries. In weight, it is a pinch of salt in 10,000 tons of potato chips. In volume, it is one drop of vermouth in 250,000 barrels of gin. In weight it is one flea in 360,000 elephants. In money, it is one cent in ten billion dollars. In 2,3,7,8-TCDD we cannot detect it analytically in fish; the limit of detection is about 10 ppt!

Second, there is no established case of any human being having been killed from ingesting 2,3,7,8-TCDD, either in food, or in water, or in any other chemical contaminated with it, such as 2,4,5-T. Therefore it is not known directly what its no-effect dose is. The no-effect dose for rats has been determined experimentally to be 0.001 microgram per kilogram of body weight per day. If we assume the same no effect dose for human beings (and there is reason to believe it is very much higher due to our exposure to dioxins over millions of years and the development of superior defence mechanisms) a 70 kilogram man would have to eat one metric ton per year of fish containing 27 ppt of 2,3,7,8-TCDD to get this no-effect dose! That would be 6 pounds of fish per day, every day of the year!

Third, Rhesus monkeys, which are closer to humans than rats, were fed 500 times as much dioxin every day. They took 7 to 12 months to die, which indicates the enormous safety factor in our government's allowable limit of 20 ppt of 2,3,7,8-TCDD in fish for human consumption.

Fourth, the levels of 2,3,7,8-TCDD in the eggs of herring gulls, which are fish eaters, from the Lake Ontario Basin have progressively shown a 50% reduction every two years over the past decade. That means its concentration is now only 1/32 of what it was ten years ago!

Fifth, there was a large explosion in a chemical plant in Seveso in Italy in 1976. Some 2000 hectares (50,000 acres) was contaminated with 2,3,7,8-TCDD and other chemicals. About 41,000 people who lived in the area have been studied since then. A small number of people, less than 1% in the most contaminated area, developed chloracne, and some showed a small increase in incidence of neurological damage and some a small increase in the incidence of cell aberations compared with an unexposed population, but no death has been established to be caused by exposure to dioxins. It is too early to assess whether or not there will be an increase in the incidence of cancer in the years to come.

Sixth, dioxins are not only produced during the manufacture of chemicals, but during the combustion of all materials containing salt or other forms of chlorine: garbage incinerators; power plants burning coal, petroleum or wood; stoves; fireplaces; campfires; volcanoes; forest fires; smoking cigarettes or marijuana; internal combustion engines; etc. Forest fires have been putting dioxins into the atmosphere for millions of years, yet we are still alive! Remember, we have been able to analyse for the very small concentration of 2,3,7,8-TCDD in fish in Lake Ontario only for about a decade. What was it a hundred years ago, or a thousand years ago? The fact that its concentration in herring gull eggs has decreased 32-fold in the last ten years must mean that we have brought the input from the manufacture of chemicals and the use of pesticides under control.

CHEMICALS IN LAKE ONTARIO

Another alarming report was published by Pollution Probe stating that 400 chemicals had been found in Lake Ontario, and suggesting that Toronto water treatment plants were not equipped to remove all these chemicals, and this again made the headlines in the newpapers and on the television news. What nonsense! As we have discussed, it is statistically certain that at least a few molecules of all chemicals, all 4 million of them, not just 400, are present in Lake Ontario! We just cannot detect them. It is impossible to remove them all! What is important is their concentration in our drinking water, accepting the fact that they are all present, at least in some small concentration.

Four years ago I received a grant to analyse the chlorine containing compounds in water and in sewage plant effluents disinfected with chlorine and with chlorine dioxide. We thought it wise to start with Toronto tap water. We concentrated the water by reverse osmosis, extracted the chlorinated chemicals with ether, and analysed them using our extremely sensitive gas chromatograph. Much to our surprise we could not detect any! In fact we found much more chlorinated organic material in our laboratory distilled water, because it had been stored in plastic bottles! I was intending to announce this publicly, but I was scooped by the Toronto Star in a big front page headline stating that Toronto water was quite safe to drink. They submitted parts of the same sample of tap water to three highly respected laboratories and none could find any chemical above the accepted safe concentration. I am glad to have our work confirmed in such a dramatic way!

CHEMICALS AND CANCER

It has been clearly established than many chemicals in our environment, most of them natural, but some man made, contribute to the complex mechanisms by which certain cells sometimes grow and multiply out of control, producing cancers of various kinds.

The remarkable fact is that the millions of cells of various types that make up our bodies remain on the average for 70 years under strict control through their genetic code, which each of us inherits from our parents. Heritable changes in the genetic code, the DNA, which we call mutations, occur very frequently from a multitude of natural causes, to which all living things have always been subjected. The real wonder is that the vast majority of these mutations do not result in some sort of sickness or disease, such as the uncontrolled growth of cells.

Our bodies forunately have repair mechanisms which rapidly correct errors in our DNA created both by natural errors in its replication as new cells are constantly produced, and by mutagens in our environment. We also have an immune system involving white blood cells and antibodies which destroys the mutated cells before too many get reproduced.

It is only when the rate of mutation exceeds the rate of repair of the DNA and the rate of destruction of the mutated cells that uncontrolled growth takes over and cancer develops. Unfortunately our defence mechanisms weaken as we grow old and the incidence of cancer increases.

The age-adjusted death rate per 100,000 people for cancer has been decreasing steadily of the last thirty years, IF THE DATA FOR LUNG CANCER ARE REMOVED.

Twenty percent of the population ultimately develop cancer, but about thirty percent of all cancers are related to smoking.

Each laboratory test for whether or not a particular chemical is carcinogenic involves a large number of animals over two or three years, and costs more than half a million dollars. Then even if the chemical does produce a significant increase above the normal cancer rate in mice or rats, it does not necessarily mean that it does so in humans.

We cannot use human subjects for such experiments, so we must resort to statistical studies of the frequency of occurrence of cancer after prolonged, unintentional, inadvertant exposure to certain chemical environments. The most clearly established epidemiologically is the steep linear relationship between the degree of cigaret smoking and the frequency of occurence of cancer of all types, but especially lung cancer. Complete elimination of smoking would ultimately decrease the incidence of cancer by as much as 30%. The banning of DDT, 2,4,5,-T, cyclamates, saccharin, PCBs, polychlorinated hydrocarbons or all chemicals, can not affect the cancer rate as much as 1%. Yet tobacco is not banned!

A steadily growing number of chemicals, fed in larger doses than we would ever ingest, has been shown to produce cancer in certain animals, but often not in other animals. Very few chemicals have been shown by statistical studies to produce cancer in humans, and, of course, none has been deliberately tested experimentally, except perhaps DDT. It is reported that the U.S. army fed large doses of DDT to soldiers during the second world war to make sure it is not harmful to humans. We don't permit this kind of study today!

The dilemma, then, is what chemicals are to be removed from the environment with the hope of decreasing the death rate from cancer, or retained for their great contribution to human welfare? A few people say that anything demonstrated to be carcinogenic with laboratory animals, regardless of the dose applied, must be banned, but this is far too drastic. With perhaps a million chemicals to be tested, the time required and the cost would be enormous, and we would still not know whether or not the few positive ones with animals would be carcinogenic in humans.

There is no hard evidence that the massive increase in the production of man-made chemicals has significantly increased the incidence of cancer, except in workers involved in the manufacture of a few of them before they were known to be carcinogenic. The evidence that smoking has substantially increased the incidence of cancer is overwhelming.

There is no question that proven carcinogens, mutagens and teratogens (chemicals which can cause deformed offspring) should be prohibited from use as food additives in any quantity which would be toxicologically significant. The problem is how to determine if a chemical is carcinogenic, mutagenic or teratogenic at extremely low levels of intake, and what level of intake would present no significant risk to the consumer.

A rapid test using specially developed bacteria which are sensitive to certain kinds of mutations in DNA has been developed by Professor Ames at the University of California and is now being used to screen a large number of chemicals to find those which cause mutations. The most potent ones can then be tested for carcinogenicity. We have such an Ames testing laboratory in my own research group, which we use to identify the mutagens produced by the chlorination of organic chemicals. The Ames test can be used to identify substances in food, in urine or in feces which are found to be mutagenic. It can also be used to seek preventive measures against cancer.

For example, Dr. Robert Bruce of the University of Toronto Cancer Research Institute has found that people fed a completely mutagen-free diet excrete mutagens in their feces, which means they are produced in our bodies. If they are fed vitamin C (ascorbic acid) or vitamin E (alpha-tocopherol) the mutagens disappear from the feces.

Sodium nitrite is a chemical used as a meat preservative which has been objected to because under certain conditions nitrite can react with amines in proteins to form nitrosamines, some of which are potent cancer producing agents. Without the small amount of nitrite used in bacon, for example, there could be many additional cases of botulism poisoning. However, each of us produces as much nitrite in our saliva as there is in a pound of bacon. So removal of nitrite from meat preservation would substantially increase food poisoning from storage of meat, but would have little or no effect on the incidence of cancer.

It is very unlikely that a simple "cure" for cancer will be found, but we must continue to hope that it will. The best we can do is to decrease our exposure to mutagens and continue to develop treatments which aid the body's repair and control mechanisms. We can decrease our exposure to known sources of mutagens, such as avoiding smoking tobacco, marijuana or any other organic matter, by putting electrostatic precipitators on smoke stacks, by improving the ventilation of work and living places, by restricting the use of the most potent man made mutagens, by monitoring and controlling radioactivity and mimimizing exposure of people to radioactivity, and by many other techniques, all of which are being practised with increasing care.

On the other front, our resistance to the growth of malignant cells which do get produced is being aided by surgery, by radiation, by chemicals, by good hygiene, by drugs and by other techniques.

The most important aid in minizing cancer deaths is early diagnosis of any malignancy and thereby starting treatment in a very early stage of the disease.

SUMMARY

The great contribution of chemicals to the advancement of mankind in a multitude of ways must be stressed: in food production; in nutrition; in health; in materials of construction; in protection of the environment; in improving the standard of living; in increasing the enjoyment of life.

At the same time, we must put the risks, existing and potential, into proper perspective. We must convince people that there is at least a very low concentration of all chemicals in normal water and food. We have been living in a sea of natural mutagens for thousands of years, and our longevity is increasing.

We must see to it that the tolerable concentration limit below which no harm is done is determined for each substance, and that manufacturing and processing keeps the concentration below that limit. The BENEFITS conferred by any chemical must be weighed against the RISKS involved in its use before banning its production, sale or use.