THE PESTICIDE CONTROVERSY

From the earliest days, mankind has had to compete with insects for its food supply. In addition, many insects propagated diseases such as malaria, or the bubonic plague which have killed millions of people throughout history. Thus, when modern insecticides were introduced in the early 1940s, they had a tremendous impact both on the world food supply and the general health of people. For instance, in the last forty years, we have seen food production more than double and the near complete eradication of diseases such as malaria. There are now about 35,000 different registered pesticides in North America. As long ago as 1980, in Canada alone, close to $400 million were spent to spray 75 million pounds of insecticides. As it is, even with the use of pesticides, it is assumed that 1/3rd of the North American food crops are lost to insects with a total cost of $10 - 15 billion.

On the one hand, over the last twenty years, more and more people have become concerned about some of the negative effects of pesticides on the environment and the effects of pesticide residues in our food. On the other hand, farmers take special pride in having a low insect-parts-to-grain ratio in their crop and in not having an insect infestation ruin the produce. This is a concern echoed in commercial sales. The irony is that the public, while interested in eliminating pesticides from the food supply, is not willing to buy wormy apples. Thus, the question should not be whether pesticides should be allowed or banned, but whether their benefits are worth the risk involved in their use, particularly if there are safe and effective alternatives available.

Early Insecticides

The ancient Greeks burned sulfur in their fields to protect their crops. This burning produced sulfur dioxide (SO₂) which is toxic to fungi, insects, and various microorganisms. This method is still used today against the red mite. However, it is only in the 19th century that chemical research started providing agriculture with a large number of compounds with insecticidal properties. Most of these were based on inorganic species containing such toxic metals as lead and arsenic or upon natural products such as nicotine. And most are highly toxic to humans. They are rarely used today. The exception is pyrethrum, found in a variety of chrysanthemum, which is still used due to its low toxicity for humans. Pyrethrum or its synthetic analogues are the active ingredients in household insecticides such as “Raid”.

The Rise and Fall of DDT

The 1948 Nobel Prize for Medicine was awarded to Paul Müller, the Swiss chemist who discovered the insecticidal properties of DDT (dichlorodiphenyltrichloroethane). This gives an idea of the impact DDT had at the time as a miracle pesticide. DDT saved millions of lives preventing outbreaks of typhus and malaria. It lead to increased food production by destroying food pests such as the Colorado potato beetle. Moreover, and this is of greatest importance, it appeared totally safe to people. In this respect, it should be mentioned that to this day, even though DDT was used for over 40 years, there have been no reports of accidental deaths in humans.

It was not until 1962 with the publication of Rachel Carson’s book Silent Spring that the public became clearly aware of the other side of DDT. The major problem was its impact on the environment. DDT is non-biodegradable and is fat-soluble. Thus, DDT concentrations increase as it goes up the food chain. Species at the top, such as fish and birds, are especially affected. Birds are also affected because DDT interferes with their metabolism of calcium. They lay eggs with weak shells which in turn can not withstand the hatching period. The near-extinction of the bald eagles in the U.S. has been associated with the use of DDT.

In addition, many species such as the housefly have become immune to DDT. DDT-resistant species use an enzyme to deactivate DDT to a less toxic metabolite, DDE (dichlorodiphenylethylene). Synergists can sometimes be used to increase the potency of DDT for such insects. A DDT synergist, such as chlorofenthol, can have a structure similar to that of DDT. The enzyme binds to the synergist and thus is rendered ineffective as far as DDT is concerned. As a result, the insect remains susceptible to DDT.

Although the immediate toxicity of DDT to humans is low, there are concerns about long-range problems. Humans, being at the top of the food chain, ingest DDT from a variety of sources (mostly meat) and then store it in the body. Studies indicate that DDT is carcinogenic for rats. At present, however, for humans there is only a statistical association showing that certain cancer patients have higher levels of DDT or DDE.

DDT has been banned in Canada since 1969 and in the United States since 1972. However, in 1992, some 300 tons of it was shipped to Peru. Since then recorded exports of domestically outlawed (in the United States) pesticides average 9 tons a day. While North America has been somewhat “cleaned up”, the concerns of other parts of the world for pest reduction have not been the same. According to a 1996 report from the International Rice Research Institute (IRRI) in the Philippines, 80% of the pesticides sprayed on rice in the Philippines are used for the wrong pests and applied at the wrong time - thereby being rendered ineffective. This problem may be widespread in many parts of the world. The World
Health Organization (WHO) has estimated that pesticides cause approximately 220,000 deaths and 3,000,000 cases of poisoning world-wide each year. (Note: 100,000,000 people die each year so this represents 0.22% of all deaths.)

There may even be long term concerns with respect to residues of DDT. Over the last fifty years there has been a 50% decrease in sperm count in males and a three fold increase in testicular cancers. Some researchers claim that this is a result of past use of DDT. The basis for their theory is that DDT, because of its structure, can act as an estrogen mimic by fitting into receptor sites for this hormone. They support their idea with the observation that, for alligators in Florida, high levels of DDE, the DDT metabolite, are associated with reproductive failure. Estrogen levels in males are abnormally high and as a consequence, their testosterone levels are too low for breeding. Females are super-estrogenized and lay abnormal eggs.

DDT’s structure also resembles that of DES (diethylstilbestrol). The latter had been used as a drug to prevent miscarriages. More than twenty years later, it was realized that a small number (0.1%) of daughters of the women who had taken the drug had developed a very rare form of vaginal cancer. It also appeared that in the case of sons, there was a higher incidence of decreased sperm counts and undescended testicles. A study published in 1995 located 548 of the 848 boys born during the trial of the effect of DES on women. They were able to interview 90% of them. Half of this group had been exposed to DES in the womb and half had not. It turned out that 15% of the men whose mothers had taken DES reported genital malformations (mostly minor). This was three times the rate of those in the unexposed men. However, there was not evidence of impaired male fertility.

Finally, it is suggested by some researchers that THC (tetrahydrocannabinol), the active ingredient in marijuana, also acts as an estrogen mimic like DDT. This would explain the lowered sperm count observed among heavy users.

New Pesticides, New Problems

Pesticides that have replaced DDT are generally safer for the environment and the organisms within it because they are biodegradable. For that reason, there are also fewer residues in food. However, most of them have much greater immediate toxicity to humans. The organophosphates, such as malathion and parathion, are derivatives of nerve gases developed during World War II. Because of their perpetual and high level of exposure, farm workers are most affected. On average, each year, there are 4,000 cases of accidental poisoning and 50 deaths in North America that can be attributed back to these substances.

The major environmental problems associated with the organophosphates is that they are particularly potnet against honeybees. This is also true for another class of compounds, the carbamates. Accidental spraying is said to have killed 400,000 bee colonies in North America, or 10% of the total. This may result in a major problem, as close to $4 billion worth of crops require bee pollination.

Although pesticide residues are low in food, there are still many concerns about their safety. DBCP (dibromochloropropane) was found responsible for the accidental sterilization of workers in three pesticide plants. In California, this pesticide has found its way into the water supply. Captan, extensively used for apple crops in Canada, was found to be carcinogenic in test animals. Health and Welfare Canada feels it should be banned but Agriculture Canada says that the risks are minimal.

The safety of certain pesticides were questioned when it was revealed that approval for use had been granted based on improper test or falsified results of an “independent testing” company. This affects about 100 pesticides out of the 3,500 registered in Canada.

Biological Controls

A number of avenues are being investigated to find alternatives to conventional pesticides. A perfect pesticide should be effective, safe, and highly specific. That is, it should eliminate the particular pest that it is suppose to, only that pest, and not hurt or harm anything else. In this respect, biological controls probably represent the most interesting approach.

Sex attractants, a class of compounds referred to as “pheromones”, are emitted (usually by the female of a species) to attract the male. Such compounds, once isolated and duplicated in the laboratory, can then be used in baited traps. This method, which is highly effective, is commercially available to determine the degree of pest infestation in the area. A farmer can then determine the best time to apply pesticides which enhances their efficacy and reduces the overall amount introduced into the environment.

Natural predators, such as ladybugs and praying mantises, are also commercially available and used on small-scale operations. However, because of their nature, they are slow-acting and lack the punch - the immediate “kill factor” - of pesticides for large crops.

Male sterilization has been effective in a number of cases. In this method, males are sterilized by radiation and released. When a female mates with a sterile male, no offspring are produced. Because, in some species, the female mates only once, this method prevents further offspring. The sterile male, by contrast, continues mating and thus prevents the
production of a large number of offspring. This method was recently used in California to fight a major outbreak of the Mediterranean fruit fly. However, it was not successful, and aerial spraying of malathion was used to eradicate the pest.

Another approach, which is only at a preliminary state of research, is to develop viruses tailored to kill a specific species. Of course, the downside of such work is that the viruses could represent a significant health problem for humans as well.

Pesticide Residues in Food

At present, alternatives to conventional pesticides, such as biological controls, do not appear to be effective alone for large-scale food production. In the meantime, if one is concerned about residues in food, a number of measures can be taken.

Most pesticides remain in the outer leaves or skin of the plant. Thus, thorough washing should be sufficient to reduce pesticide levels to negligible amounts. Certain people will insist on peeling all fruits but this will also cause the loss of some nutrients. It should be noted that frozen products tend to have lower levels of pesticides than those sold at local supermarkets. Vegetables and fruits used for freezing are washed immediately after picking, preventing further absorption of any remaining pesticides.

Buying “organically grown” products unfortunately does not guarantee pesticide-free produce as there is no legal definition of the term. There are “certificates” but there are no agencies presently established to monitor this certification process.

Growing one’s own food requires both space and time but offers the best assurance of pesticide-free produce. However, the garden should be situated at least 300 feet from any heavily travelled road due to the aerial transport of contaminants. A recent study has shown high levels of lead - a residue of leaded gasoline - in vegetables produced in local gardens despite the fact that lead has been banned in North America for many years.

One carbamate insecticide of considerable importance is “Sevin”, made by the Union Carbide Company by the following reaction:

\[
\text{Methylisocyanate} + \text{Methane} \rightarrow \text{Methanol} + \text{Carbon Dioxide} + \text{Water}
\]

The methylisocyanate was the compound that was accidentally released during the Bhopal, India disaster. Such “accidents” heighten public concerns over the safety of pesticides as the assumption is that if one of the components is so toxic, then the compound must also be toxic for humans. This is not necessarily a valid assumption - although warranted in this case.

Pesticide Pandemonium

“The Big Apple bans little ones from school lunches” screamed the headlines. Los Angeles, Chicago, and a host of other cities followed suit. What was going on? Apples had always represented health and good nutrition - “an apple a day keeps the doctor away”. Suddenly, apples were to be avoided. They had become a peril to our health and a symbol of modern technology gone astray.

The hazards of eating apples were pointed out in a highly publicized report by the Natural Resources Defence Council (NRDC), a U.S. based, environmentalist organization. The report stated that “allowable pesticide traces in farm produce may cause cancer and nerve damage in children” and that “up to 6,200 children now aged five or younger will go on to develop cancer as a result of pesticide residues in fruits and vegetables.” The media considered this study a real “scoop” and interpreted it as proof that pesticides are causing cancer. Nowhere was it mentioned that the release of this report violated the fundamental criterion of scientific publication, namely, the peer review process. This accepted method for the circulation of scientific findings ensures that all of the evidence is scrutinized prior to release by independent referees - experts in the field. Peer review is a safeguard against poorly designed studies and the dissemination of information which may be misleading.

The chemical diaminozide (“Alar”), a plant growth regulator used to keep apples from dropping prematurely, was singled out as particularly dangerous in the NRDC report. The expressed concern was that its decomposition product, UDMH (unsymmetrical dimethylhydrazine) has been linked to cancer in test animals. Was the alarm over Alar justified? Was the government callously exposing children to substance which would surely cause cancer? It is certainly worthwhile and instructive to examine the scientific validity of these claims with five questions in mind. Why are pesticides used? Are there any alternatives to their use? What is the extent of pesticide residues in our food? What are the health risks
associated with these residues? Do the risks of using pesticides outweigh the benefits?

Why are pesticides used?
Legally, pesticides encompass insecticides, herbicides, and fungicides. They are used to control the over 10,000 destructive insect species, the 8,000 fungi, and the over 2,000 types of weeds which threaten our food supply. In North America, the use of agricultural chemicals has freed most of us from having to till the soil, still a necessity for about 75% of the people in the developing countries. Insecticides have also gone a long way towards controlling insect borne diseases such as malaria, bubonic plague, typhus, and yellow fever. Can we get along without these chemicals? Some people point out that our grandparents did just fine without pesticides. Unfortunately, the truth is that they didn’t do just fine. In the “good ol’ days”, (which, to them, were invariably “these trying times”) the average life expectancy was under fifty, fruits and vegetables were only available “in season”, and then only if they could be saved from the armies of maggots, beetles, worms, caterpillars, aphids, ticks, and ants which inhabited the fields.

Furthermore, the same amount of land which fed 2.3 billion people in 1900 now has to feed 6 billion. Modern science is providing some potential alternatives to pesticides through the use of insect sex attractants and the introduction of beneficial predatory insects. The romanticized ideal of “organic farming”, at least on a scale large enough to feed the entire population, does not appear to be realistic. Organic produce tends to come from small farms which can sustain losses by catering to that segment of the population willing to pay dearly for food perceived to be risk free. The utopian concept of zero risk, however, does not exist. Substances produced by fungi in the absence of fungicides can be more hazardous than synthetic chemicals. The compound patulin, a fungal metabolite which may be found in “organic” apple juice, is carcinogenic in animals.

Are there pesticide residues on our food?
Yes, in some cases, there are. Our analytical detection capabilities are such that residues can be found in the parts per million and, in some cases, the parts per billion range. This is pretty impressive, seeing that one part per billions corresponds to one second in thirty two years or like being able to detect a single drop in 50,000 litres of liquid. In a study commissioned by the magazine “U.S. News and World Report”, samples of raw and processed fruits and vegetables were collected randomly from around the country and analysed for those pesticides which are suspected or known to cause cancer in animals. The tests revealed that 94% of the samples had no detectable residue and the rest had less than one quarter of the levels allowed by law. A similar study involved random sampling by the Food and Drug Administration in the U.S. for the fungicide “Captan”, believed by some to be a human carcinogen, revealed that only 4% of the samples had any residues at all and these were in the range of about one tenth the legal limit. Alar residues are found on less than ten percent of apples and on most varieties not at all.

Again, when present, the residues are well below the allowed tolerances. The dire predictions about cancer rates, however, assume much higher degrees of contamination. NRDC alleges that government limits were not designed with children in mind, and since children consume proportionately more fruits, juices, and drinks than adults, their health is “being traded off for keeping apples on the tree longer”. Although this comment may be somewhat over-dramatic, there is no question that Alar is a special case since the fruit industry can adjust to survive without it.

Are there hazards associated with pesticides residues?
The question which provokes the greatest emotional debate on the pesticide issue is undoubtedly the one dealing with the potential health hazard posed by residues. Defenders of pesticide use speak of the “odious and hysterical campaign waged by panic sowing irresponsible environmentalists”, while their opponents are tired of “government and industry apologists” and warn of a “monstrous cancer epidemic” being unleashed upon the public. The truth, as with virtually every controversial issue, is somewhere in between the extremes.

There are essentially two ways by which the health risks of pesticide residues can be estimated. Animal feeding studies can determine the degree of toxicity of a compound in test animals and an examination of human populations exposed to high levels of pesticides can gauge their effect on people. It is important to remember, however, that while such studies are important in risk analysis, neither of these methods can prove anything about trace amounts of residues in food.

First, let us examine animal studies. The standard technique involves feeding a compound to animals in ever-increasing doses until some effect on their health is noted. The maximum amount per kilogram of body weight for which there is no effect is then divided by a safety factor of one hundred to establish human exposure limits. Since humans are considerably different from rats, there is a great deal of controversy about which animal tests actually tell us.

Arsenic compounds, for example, are carcinogenic in humans but not in test animals. Most substances which cause cancer in animals have not been shown to cause cancer in humans. In fact, of the hundred of substances which have been tested for carcinogenic activity, there are only ten for which sufficient information is available to label them
“carcinogenic” both in man and animal. Animal tests are also difficult and expensive to carry out. About three years, 600 animal, and over a half a million dollars are required to run a test on a single compound, a test which may turn out to be inconclusive in human exposure terms.

Then there is the critical question of the so called “threshold effect”. Is there some minimal exposure below which there is no health hazard or can cancer be caused by one molecule of a carcinogenic substance? Although both sides of this question can be argued, it is difficult to see how anyone could avoid cancer if there were no threshold. We are constantly bombarded by naturally occurring carcinogens in amounts and relative potencies far greater than pesticide residues, yet most of us do not get cancer. The apple panic was provoked by the finding of the Alar decomposition product in the fruit. Yet, the same kind of hydrazines occur in mushrooms, acting as natural insecticides.

In fact, natural pesticides make up 5 - 10 % of the weight of most plants and we probably consume 10,000 times as much of these as we do in pesticide residues. Indeed, these chemicals could not be extracted from plants for use as “organic pesticides” because they would fail every animal toxicity test! Undoubtedly, then, the human body can repair some degree of damage and cancer occurs only when exposure is such that the natural defences are overwhelmed. Basically, animal testing gives us a useful guide for degree of carcinogenicity in animals and is used to predict possible effects in humans only because there is no other satisfactory model. The large majority of studies on Alar, involving a variety of animal species, have shown no carcinogenic effects. Only with extremely high doses, about 4 million times human exposure levels, are tumours noted in some species. These levels may make extrapolation to human unreliable since the animals immune system is in all likelihood compromised by the massive exposure.

There have also been a large number of studies focussing on the health of farmers and of workers in the pesticide industry. All the reports agree that pesticides can cause acute reactions through inhalation or skin exposure. Proper handling and safety gear can virtually eliminate these problems. Although an immense amount of data has been collected on possible long term effects, we are left with the conclusion that whatever health risks may exist for agriculture workers, they are so small that they escape the power of epidemiological studies to detect them. There is one association, however, that between non-Hodgkins lymphoma and the use of the herbicide 2,4-D by Kansas farmers, which is presently being seriously examined. An association can not, of course, prove cause. For example, there is a strong association between skirts and breast cancer but obviously the wearing of a skirt does not cause the disease. There is no compelling evidence of any kind of a cancer epidemic among agricultural workers who are exposed over long periods to much higher doses of pesticides than the average public.

One of the most widely used quotes by groups critical of current chemical use is that “scientists agree that up to 90% of cancers are environmentally caused”. This statistic, which is true enough, is then usually interpreted to mean that our inappropriate, shortsighted, and profit motivated use of chemicals, such as pesticides, is now coming back to haunt us. A corollary to this argument, of course, is that if we can control our greed and harness an out of control technology, we can eliminate these cancers.

The fact is that the use of the word “environmental”, in the above context, does not mean “synthetic chemical” at all. An examination of populations around the world reveals a diversity of cancer patterns. Stomach cancer rates are five times higher in Japan than in North America, nasal cancer rates are high in China, mouth cancer is unusually common in India. These cancers are not genetic, as illustrated by the fact that second generation Japanese in the U.S. are afflicted with the same cancers as the rest of the American population. They are, therefore, environmental - a product of the environment in which the victim is raised and lives.

The term environmental encompasses viruses, smoking, drinking, sexual practices, dietary patterns, exposure to natural radiation, and different soil constituents, as well as natural and industrial carcinogens. Quite simply, cancer is not a disease of advanced industrialization. Even though the number of man-made chemicals in the environment has increased several hundred-fold in the last fifty years, cancer rates in North America have not changed significantly except for stomach cancer which has declined dramatically and lung cancer which, due to smoking, has increased. Alarmists delight in pointing out that since 1900, the percent of deaths attributed to cancer has increased by 400%. This, of course, is true. But it is not a reflection of increasing exposure to chemical contaminants in the environment. Rather it is a reflection of the fact that we are no longer dying of tuberculosis, pneumonia, influenza, and other diseases which were prime killers at the turn of the century. In fact, the increased life span that we presently enjoy is a chief cause of this change. People live long enough to get cancer instead of dying at an early age. In addition, many early deaths from cancer were mis-diagnosed. Cancer frequency, however, has not changed significantly throughout the industrial era - a “monstrous cancer epidemic” has not materialized to date.

Do the risks of pesticide residues outweigh the benefits of eating fruits and vegetables?

We have seen so far that there is little hard scientific linking pesticide residues to any human health risk. Even if there is a risk, it has to be weighed against the benefits of eating fruits and vegetables. These benefits are overwhelming. A recent report has linked a lack of fruits in the diet with oral cancer. There is evidence that the risk of colon cancer can
be reduced by a diet high in fruits and vegetables. Compounds in cabbage and broccoli may reduce the risk of cancer. Study after study has shown an inverse relationship between eating fruits and vegetables and heart disease, the nation’s number one killer. The soluble fibres in apples can help reduce blood cholesterol levels. One could, in fact, advance an effective argument that removing one apple a day from children’s diet is a hazard to health. Indeed, this hypothesis could be backed up by statistics which are just as meaningful as those used by the Natural Resources Defence Council which prompted the apple ban.

The NRDC is a reputable organization which has raised legitimate concern. There is a difference, however, between focussing on a legitimate concern and creating public panic. In news conferences and on talk shows, hypotheses and conjecture were passed off as facts, triggering an unwarranted paranoia about the food supply. People were repeatedly urged to contact their government representatives who had failed to protect them from the pesticide cancer threat.

There is no question that pesticide abuse exists and that modern agriculture could provide us with a plentiful food supply with a more limited use of pesticides. Watchdog groups play an important role in communicating public concerns to government and industry, and can help curb the use of chemicals for which risks may be down-played in favour of financial profit. A significant percentage of pesticides, for example, are used only to enhance the eye appeal of the produce. Based upon the NRDC report, the Environmental Protection Agency in the U.S. is re-examining its pesticide use.

Risk Analysis

The real problem with the type of report released by NRDC, however, is that most people are not easily able to evaluate risk. Their logic usually involves the sequence: “it is there, it is toxic, it is, therefore, hazardous”. The unfortunate conclusion of this logic may be to eat fewer fruits and vegetables. Such thinking violates the prime principle of toxicology, that “only the dose makes the poison”. To evaluate risk properly, we must take into account both dose and exposure. Admittedly, this is a very difficult concept for the general public to master and a lack of understanding of toxicology has led many a well-meaning person to crusade for the elimination of relatively small risk which are perceived to be catastrophic. An example is the actress Meryl Streep. She has campaigned vigorously and passionately against “cancer causing” pesticide residues. Her perspective of the problem, however, has to be questioned when she appears on talk shows and counsels people to get to know the produce manager in the supermarket because “he may be as important as your pediatrician”.

Risk assessment is a complicated endeavour, requiring extensive scientific background. Risk evaluation, based on human experience, can yield meaningful numbers. We know that about 50,000 people are killed in car accidents in North America every year, and therefore the risk of dying in an accident during a given year is about 1 in 5,000. Similarly, the risks of being hit by lightning or drowning while canoeing can be calculated. These kinds of statistics, however, are very different from cancer risks derived by extrapolation from animal studies.

In these cases, science can not give precise values but rather scientists generate a “risk estimate”. Quoting these numbers to the public at large gives the impression that the risks are known with much greater certainty than is actually the case. For example, the statement that 6,200 children will develop cancer as a consequence of Alar exposure is based on estimates and extrapolations - not on well developed risk assessment. It should be understood that it is also possible that no child will ever develop cancer due to their exposure to Alar. Feeding studies shows that mice and rats exhibit dramatically different sensitivities to Alar. The estimate also ignores the fact that less than 10% of apple products actually contain residues and does not take into account the possibility of a “threshold effect”. It should be kept in mind that it is entirely possible that long-term ingestions of say apples, at a high level, might cause certain problems associated with one of the many hundreds of molecules that are naturally present in the apple. It is essentially impossible to thoroughly test each of the naturally-occurring compounds in our food supply.

Even the certainty that a chemical causes an adverse effect at some exposure in a test animal does not tell us that there is an effect in humans exposed to small doses. Indeed, after 25 years of production and use, there is no epidemiological evidence that Alar causes any kind of cancer in humans. The public, however, demands certainty. It actually flatters science by believing it can do more than is actually possible. Science can never prove that Alar, or any other substance, does not cause disease in humans. Such proof would require that the cause of every human ailment be accurately known. Proving that something can not happen is clearly impossible, yet it is the lack of such proof upon which much public fear is based.

The media can also be faulted in creating an epidemic of apprehension. Premature, incomplete, or exaggerated information, often tainted by special interests, is trumpeted as factual and anything less than an absolute guarantee of safety by scientists is greeted with cynicism. The glut of unduly alarmist information leads to a fear of “chemicals”, which is in itself a disease leading to stress and all its consequences. The prevailing attitude is “prove that there is no risk!” But safety is relative, not absolute. The widely asked question: “is our food safe?” can never be answered because it is the wrong question to ask. What we really need to know is whether the benefits of eating any food outweigh the risks. In the
case of fruits and vegetables, even those tainted with trace amounts of pesticides, the answer is “yes”. Let us remember
that in most disease investigations, one has a disease and looks for a cause. In the case of exposure to trace chemicals, we
do not even know that a disease exists.

Our food supply today is better and safer than it has ever been. Our life expectancy is longer than ever before, partly due to good nutrition. A moderate, varied, balanced diet can minimize exposure to any potentially hazardous substance, whether natural or man made. There are, of course, a number of problems which have to be addressed. In addition to pesticide residues, there are worries about additives in processed food, hormones in meat, lead in canned goods, salmonella in chickens, E. coli in hamburgers, PCBs in fish, and dioxin in milk. Extensive publicity, based as much on emotion as on fact, has created the impression that these problems are ominous and life threatening. It is interesting that in our quest for immortality, we become intolerant of small risks and many times ignore action opportunities against smoking, drinking, drug abuse, excessive fat consumption, and environmental pollution.
Why use fertilizers?

Use of fertilizers is needed for all types of long-term crop production in order to achieve yield levels which make the effort of cropping worthwhile. Modern fertilizer practices, first introduced more than a century ago and based on the chemical concept of plant nutrition, have contributed very widely to the immense increase in agricultural production and have resulted in better quality food and fodder. As a beneficial side-effect, the fertility of soils has been improved resulting in more stable yield levels, as well as in a better (nutrition-induced) resistance to some diseases and climatic stress. Furthermore, the farmer’s economic returns have increased due to more effective production.

The purpose of fertilizer use, especially for higher yields, is identical in temperate and tropical climates:
- to supplement the natural soil nutrient supply in order to satisfy the demand of crops with a high yield potential
- to compensate for the nutrients lost by the removal of plant products or by leaching, etc.
- to improve unfavourable or to maintain good soil conditions for cropping.

Nutrients required by plants

Plants contain practically all (92) natural elements but need only 16 for good growth. Thirteen of these are essential mineral nutrient elements, commonly abbreviated, though with less precision, to "nutrients". They must be provided either by the soil or by animal manure or mineral fertilizer. Some other mineral nutrient elements, e.g. Na, Si, Co, have a beneficial effect on some plants but are not essential.

Essential mineral nutrients (13) required for growth (of equal importance physiologically):

Macronutrients (6) of which the critical contents in plants are 2-30 g/kg of dry matter:

- Major nutrients (3), applied in fertilizers for almost all crops on most soils:
  - N = nitrogen (taken up as NO$_3^-$ or NH$_4^+$)
  - P = phosphorus (taken up as H$_2$PO$_4^-$ etc.)
  - K = potassium (taken up as K$^+$)

- Secondary nutrients (3), applied in fertilizers mainly for certain crops on some soils:
  - S = sulphur (taken up as SO$_4^{2-}$)
  - Ca = calcium (taken up as Ca$^{2+}$)
  - Mg = magnesium (taken up as Mg$^{2+}$)

Micronutrients (7) of which the critical contents in plants are 0.3-50 mg/kg of dry matter:

- Heavy metals (5):
  - Fe = Iron, Mn = manganese, Zn = zinc, Cu = copper
  - (Fe, Mn, Zn, Cu taken up as divalent cation or chelate)
  - Mo = molybdenum (taken up as molybdate MoO$_4^{2-}$)

- Non-metals (2):
  - Cl = chlorine (taken up as Cl$^-$)
  - B = boron (taken up as H$_2$BO$_4^-$, etc.)

Some beneficial nutrients useful for some plants:

- Na = sodium (taken up as Na$^+$; can partly replace K for some crops)
- Si = silicon (taken up as silicate, etc., e.g. for strengthening cereal stems to resist lodging)
- Co = cobalt (mainly for N-fixation of legumes)
- Cl = chlorine (useful for some crops in greater than essential amounts, for osmotic regulation and improved resistance to some fungi)
- Al = aluminium (perhaps beneficial for some plants, e.g. tea?)
Van Helmont and the Elements

Van Helmont rejected the theory of the four elements and three principles as taught by Paracelsus, and the “heathen” theory of a primary matter of Aristotle. He asserted that the true elements are air and water. Neither of his two primary elements is convertible into the other and an element cannot be reduced to a simpler state. The other two so-called elements (fire and earth) do not deserve the title, since fire is not a form of matter at all and earth can be formed from water. He points out that water, with heaven and earth, was formed on the first day in the account of Creation in Genesis. He describes the famous “tree experiment” to prove that “all vegetables proceed out of the element of water only”:

“I took an earthen vessel (clay pot), in which I put 200 pounds of Earth that had been dried in a furnace, which I moistened with rain-water, and I implanted therein the trunk or stem of a willow tree, weighing five pounds; and at length, five years being finished, the tree sprung from thence, did weigh 169 pounds, and about three ounces; But I moistened the earthen vessel with rain-water, or distilled water (always when there was need) and it was large and implanted into the earth, and least the dust that flew about should be co-mingled with the earth, I covered the lip or mouth of the vessel, with an iron-plate covered with tin, and easily passable with many holes. I computed not the weight of the leaves that fell off in the four Autumnes. At length, I again dried the earth of the vessel and there were found the same 200 pounds, wanting about two ounces. Therefore, 164 pounds of wood, bark, and roots arose out of water only."

The conclusion is mainly correct, since a tree is largely water (about 50% for a willow) but it is an irony of fate that van Helmont did not know the part played by the carbon dioxide in the air, since, as he has shown, he was the first to realize the existence of this gas, to which he gave a special name. In the idea, but not the performance, of this famous experiment, van Helmont had been anticipated by a century and a half in a work of Nicolaus of Cusa.