INCERATION AND HEALTH
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"***What is it that is not poison ? All things are poisons and none that are not. Only the dose decides that a thing is not poisonous***" **(Paracelsus, 1538)**

Our nation is producing waste at an enormous rate. In recent times we have generated double the amount of household and commercial waste than we did fifteen years ago. Our media constantly and quite justifiably feature our rapidly accumulating waste mountains and expose the political procrastination on waste management policy that has led to the current impasse. But the problem transcends the political landscape. The traditional political parties are divided on solutions to the waste dilemma while the relatively new arrivals, the green fraternity, protest that the only solution is "zero waste". Even the public are ambivalent on the solution—they like to purchase goods in elaborate wrappings while they decry government inaction on making waste disappear and nobody wants a waste disposal site of whatever form in their locality—more familiarly known as the NIMBY syndrome. On the positive side, however, the recent 'plastic bag' initiative has been a singular success for the Minister and the Department of the Environment but there has been little real progress elsewhere.

Ireland has a somewhat delinquent record in complying with European Union legislation on environmental matters and this is particularly true of waste disposal. Official EU policy on waste management is summarised in a diagrammatic hierarchical form in Fig. 1 in which prevention, minimisation, re-use and recycling are the preferred ways for dealing with waste. Energy recovery and disposal, euphemisms for incineration and landfilling of waste, respectively, are the least preferred options. Very slow progress has been made in the areas of re-use and recycling and prevention of waste. Nowhere is this more obvious than in the major litter problem that is evident daily in our cities, towns and countryside. And several hundred thousand tonnes of waste have been dumped in the Co. Wicklow countryside in recent years. Since the Litter Pollution Act of 1997 there has been eight-fold increase in litter spot fines by local authorities. Still, only 10% of household and commercial waste is recycled or re-used. Despite our poor performance in adopting and implementing the preferred waste management strategies there is hardly a more emotive issue than waste disposal among the public in general in Ireland. But we must now urgently turn our attention to compliance with the internationally recognised waste management hierarchy. Otherwise, human health, the environment and national economic growth will be irreversibly damaged for years to come and our image as a green and pleasant land may be lost forever.

Energy recovery or incineration of waste has been at the forefront of the waste management agenda of the Department of the Environment and of state bodies such as Forfas and the Environmental Protection Agency for years. It has been regarded as superior to waste disposal by landfill for several reasons— a rapid process that produces useful electricity and heat and a large reduction in the volume of material after burning compared with the numerous, ugly new holes in the ground required for landfill which remain biologically active for up to fifty years. And it is higher up the

EU 'hierarchy' than landfill. Although both incinerators and landfill sites produce potentially toxic chemicals in their atmospheric emissions and notwithstanding that landfilling may also cause groundwater pollution, the greatest threat to health is perceived to be from incinerators. The Irish public and local politicians appear to have taken a particular dislike to incineration as a solution for our burgeoning waste problem as indicated by the number of objections to the incinerator plan for Louth/Meath area recently and the reluctance of local councillors to adopt regional waste management plans. But, plans are now taking shape to have a total of five regional municipal waste incinerators, one each in the South, West, North-east, East and South-east of the country.

Incineration-what is it?

In the current context the term incineration refers to burning material in a combustion chamber or burner at 1,000^{o}C or more under highly controlled combustion conditions: the oxygen concentration is regulated accurately, the time of burning of each amount of material, the residence time, is kept constant, the emissions are subjected to controlled cooling and the gases and particles are cleaned by special filters before being released to the atmosphere. The overall process is regulated through an EU incineration directive which is administered by the Environmental Protection Agency. Such incinerators are expensive with the initial cost for one burning 100,000 tonnes of waste per year running at €50-100 million.

We are all very familiar with burning processes such as domestic fires, bonfires and back-garden rubbish burning but these occur under highly uncontrolled burning conditions: for example, the temperature may fluctuate between 200 and 400^{o}C in the burner, usually a modified barrel or bin, and there is no control of oxygen concentration in the burner or of the gases or particles which freely disperse into the surroundings.

Of course, there are emissions from incinerators burning municipal waste-household and commercial- and it is these emissions that generate such high levels of concern among the public. People rightly worry about the potential negative effects that these facilities may have on human health and the general environment. The major combustion products from incinerators, aside from harmless carbon dioxide and water, are shown in Table 1. The concentrations of each of these compounds that are emitted are regulated by specific criteria attached to the EU incineration directive. The limiting concentrations are set to protect human health and that of plants and animals also. This is also the guiding principle set out in the Air Pollution Act (1987) and similar principles of human health and environmental protection are embodied in the legislation of the other EU member states and in the US Clean Air Act and its amendments.

Public resistance to incineration

Public resistance to incineration is high as judged by responses to recent planning proposals to site incinerators in the five regions of the country mentioned already above. This resistance appears to be mainly concerned with the possibility of generating the very toxic chemicals known as dioxins during the incineration process and their subsequent dispersal into the atmosphere in the emission process. It is argued that dioxins will have adverse health effects such as carcinogenicity i.e. cause cancer either directly or indirectly, are toxic to the immune system of humans and cause contamination of the land in the vicinity of the incinerator. Indeed, more extreme views from some of the green movement have labelled incinerators as 'dioxin factories'. On the other side, some industrial commentators, proponents of incineration, claim that modern municipal incinerators are 'safe' and that living in their proximity poses no health risks. It is from this conflicting backdrop that scientists working in the areas of biochemistry, pharmacology and toxicology have to put the scientific record into an objective perspective that can be understood and appreciated by reasonable people.

Although very small amounts of toxic chemicals (e.g. metals) other than dioxins are emitted by even the best modern incinerators objectors always focus on the dioxins even though they are present in the lowest amounts in the emissions—in amounts so infinitesimally small as to be unimaginable. For this reason it is my contention developed over several years that the only significant public health issue associated with the incineration of municipal waste is the presence of dioxins and their potential toxicity.

Dioxins - nature and sources

Dioxins are organic chemicals containing several atoms of chlorine in addition to carbon, hydrogen and oxygen arranged in cyclical form in space. The molecular shape of dioxin is shown in Fig.2 where the most toxic of the dioxins, known as TCCD, has a double doughnut shape joined in the middle by two oxygen atom bridges. Dioxin first came to the public eye when it was discovered to be a contaminant of the defoliant spray agent orange used to clear jungle vegetation during the Vietnam war about 1970. Since then we know it was released accidentally during an explosion at a herbicide factory in Seveso, Italy in 1976. There were further dioxin contamination incidents in the United States most notably the infamous Love Canal incident. An inventory of sources and levels of dioxins produced by various processes in the United States has been published by the United States Environmental Protection Agency and is shown in part for the last complete set of data for 1995 in Table 2. The highest total contribution came from the incineration of municipal waste but, unexpectedly, the uncontrolled burning of waste in backyards, so-called barrel burning, produced half as much again. Other significant sources were medical and hazardous waste burning and residential wood burning. Although the relative amount of dioxins produced by cigarette smoking is small it may be significant for the individual smoker since it is directly inhaled into the body.

Studies in the United Kingdom in the 1970s and 1980s showed that many municipal waste incinerators released significant quantities of dioxins during these decades. Since then there has been gradual improvement in incinerator technology, both in combustion technology and filtration of the emission gases, leading to a 100-fold or more decrease in dioxin emissions. When improved technology is combined with separation and segregation to remove plastics such as PVC from waste incinerator performance is further enhanced leading to virtually negligible dioxin emissions. However, emission levels never reach zero but they are well below the legal limit of 0.1 ng per cubic metre set by the EU. It is estimated that emission of dioxins from the

300 municipal waste incinerators in the EU will have decreased by 200-fold over the period 1995-2005.

How toxic are dioxins ?

As already indicated dioxins contain several atoms of chlorine in the molecule; they are often called organochlorines because of their chemical similarity to the now banned insecticide DDT. They are not very complicated molecules as is often claimed. But they are very insoluble in water and tend to accumulate in our fatty or adipose tissue when they enter the body. Once there they are metabolised and eliminated very slowly from the body and it is these properties that create much of the anxiety associated with exposure to dioxin. There are some seventeen types or molecular forms of dioxin which have significant toxicity in humans and various animals. It is generally believed that the most toxic of the forms of dioxin is that containing four chlorine atoms on carbon atoms numbers 2,3,7,and 8 as illustrated in Fig. 3; these are usually abbreviated TCDD and TCDF in reference to the dioxins and furans, respectively. Dioxin is often said to be the most toxic chemical known but this is incorrect. The toxic protein produced by the food poisoning bacterium Clostridium botulinum, botulinum toxin, enjoys the latter status by a large magnitude. Interestingly, this is the active constituent of the anti-wrinkle treatment 'botox', a widely used facial treatment used by women ! Of course, the principal dioxins are in the super-toxic class of chemicals when one compares all chemicals on a relative toxicity scale. But most of the notoriety of dioxin toxicity can be attributed to the fact that it is some 1,000 times more toxic to the guinea pig than to humans, hamsters and several other species.

As already stated dioxins have a number of toxic actions in humans: they have been classified as definite human carcinogens by the World Health Organisation since 1998; they may also have adverse effects on the immune and hormonal systems of the body; and they have been implicated in causing developmental defects during foetal gestation. But it is for their potential carcinogenicity that they are most feared in the environmental arena and there is a vast scientific literature on the topic with very notable toxicity evaluations published by both the WHO and the United States Environmental Protection Agency (USEPA) since 1994. One thing is clear though: dioxins do not cause changes in the hereditary material DNA as do the toxic chemicals present in cigarette smoke i.e they do not cause mutations in genetic parlance. At a biochemical level they bring about their toxic effects by a process similar to that of the action of the steroid hormones.

Putting toxicity in context

The air quality policy of the EU is now in line with that of USEPA, namely, that it incorporates the idea that air quality refers to certain *acceptable concentrations of pollutants* in the atmosphere. The policy does not aim at achieving *zero concentrations of pollutants* in the air or other media be it soil or water. This would not only be scientifically unachievable but would also be highly impractical and a waste of economic resources. Nevertheless, the majority of "green" parties and objectors to high technology developments in pharmaceuticals and biotechnology insist on *zero emissions* and *zero waste* strategies. When this policy is applied to exposure to dioxins we can assess their potential human toxicity by applying the parameter *acceptable daily intake* or ADI to the amount of dioxins that we take into our bodies on a daily basis primarily from the various foods in our diet. ADI is defined as the level of a potentially toxic compound which we may ingest daily for our lifetime, usually 70 years, without incurring any adverse health effects. In the case of dioxin intake in humans the WHO has set the value of the ADI in the range 1-4 pg per kilogram of body weight per day. Table 4 shows the contributions of the various foods in our diet to our daily intake of dioxins. It is notable that less than 1% of intake is from air and that most come from meat, fish and dairy products. The explanation for this lies in the fact that dioxins emitted from various burning and incineration processes end up in soil, grass and water and find their way into the human food chain through the consumption of meat and milk from herbivorous animals and from fish. Based on limited data for the dioxin content of Irish foods, which are very low compared with US and European levels, it is highly likely that individual dioxin intake in Ireland is well within the ADI set by WHO. However, the intake of dioxins in several other countries and in the US are at the upper limit of the ADI and in some cases exceed it albeit by a small amount. Present evidence indicates that dioxin intakes by infants in some mainland European countries exceed the ADI because of the relatively high levels in human milk; however, WHO considers that the benefits of breast feeding outweigh the risk of adverse effects from dioxins.

Acceptable risk and dioxins

The concept of acceptable risk arises out of the fact that science cannot prove that any chemical, process or activity is entirely or absolutely safe. This is illustrated in Table 5. We drive our cars on any pretext; we swim in lakes, rivers, seas and oceans; we fly from city to city, country to country and continent to continent without any apparent worry. The level of risk of death in the case of driving a motor vehicle is particularly high. We all run risks in our every day activities. Much of the time we ignore them such as when we sit in to our cars. Risks arise in sports, business, in personal relationships, in the laboratory, in the doctor's surgery, the hospital, in the factory, on the building site and even in political calculations. Risk is ubiquitous ! In society generally, we act to gain some benefit or advantage by accepting some danger or risk. On a collective basis, we make numerous trade-offs on a benefit/loss model. This is the situation that we face in dealing with waste.

Many factors must be considered in arriving at an acceptable risk level. It must be pointed out that "toxicity" is not equivalent to "risk" and that the degree of risk should guide public health policy. Scientists, doctors and managers need to improve their communications with the public on the matter of risk. The public understanding of risk information is generally poor and the public's perceptions do not match that the judgements of experts. But this begs the question--how much risk is too much risk ? Many scientists would suggest that an acceptable level of risk would be in the range 1 in 100,000 to 1 in 1,000,000; this corresponds to the level of risk defined by the concept of the *virtually safe dose*, a concept well recognised internationally in toxicology when assessing the potential toxicity of cancer-causing chemicals. Thus one cannot guarantee that s chemical or process is absolutely safe in everyday terms but one can assign a probability of suffering an adverse effect, disease or death sufficiently small to be regarded as negligible. In this context, it must be understood that ***zero*** risk is meaningless. The WHO has recently suggested acceptable levels of risk which the governments of countries might adopt within a national framework of risk management, namely, 1 in 10,000, 1 in 100, 000 and 1 in 1,000,000.

The increased risk of contracting cancer from dioxins emitted by a 100,000 tonne per annum incinerator can be calculated to be close to 1 in 100,000 over a lifetime on a worst-case basis using available published data; the corresponding risk of death would be 1 in 200,000. If average toxicity data are used, the respective risks would be as low as 1 in 1,000,000 and 1 in 2,000,000, respectively. These levels of risk are extremely low and directly in line with the levels of risk that WHO have suggested that national authorities might adopt as acceptable risk levels.

Conclusion

If we are to move ahead with managing our waste in a responsible manner scientific considerations would suggest that incineration, a very low risk process, should be used to treat more difficult, recalcitrant wastes in a programme in which minimisation, recycling and reuse would receive the highest priority as outlined in the EU hierarchal approach. Incinerator performance should be monitored more frequently and independently than required by EU Directive to give the public sufficient assurance that exposure risks are kept to the levels stated above.

References

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Table 1. Compounds emitted from incinerators

Toxic organic compounds
Chlorinated dioxins and furans (PCDDs, PCDFs)
Polychlorinated biphenyls (PCBs)

Inorganic gases
Carbon monoxide, hydrogen chloride, hydrogen fluoride, nitrogen oxides, sulphur dioxide

Toxic metalloids and metals
Arsenic, Cadmium, Lead, Mercury

Table 2. Dioxin sources and levels (1995, gTEQ/year)

Municipal waste incineration	1250
Barrel burning, domestic waste	628
Medical Waste	488
Smelting	271
Hazardous waste incineration	156
Sewage	77
Residential Wood burning	63
Petrol engines	2
Smoking cigarettes	1

Table 3. Contribution of foods to the dietary intake of dioxins

Component	%
Meat and meat products	38
Fish	8
Cow’s milk	23
Milk products	12
Fat and oils	19
Air	<1

Table 5. Risk of an individual dying in any one year from various causes

Factor/activity	Annual risk
Smoking, 10 cigarettes/day	1:200
All natural causes	1:850
Influenza	1:5,000
Driving motor vehicle	1:8,000
Leukaemia	1:12,500
Playing soccer	1:25,000
Accident at work	1:44,000
Homicide	1:100,000
Hit by lightning	1:10,000,000

Fig. 1 EU Waste Management Hierarchy

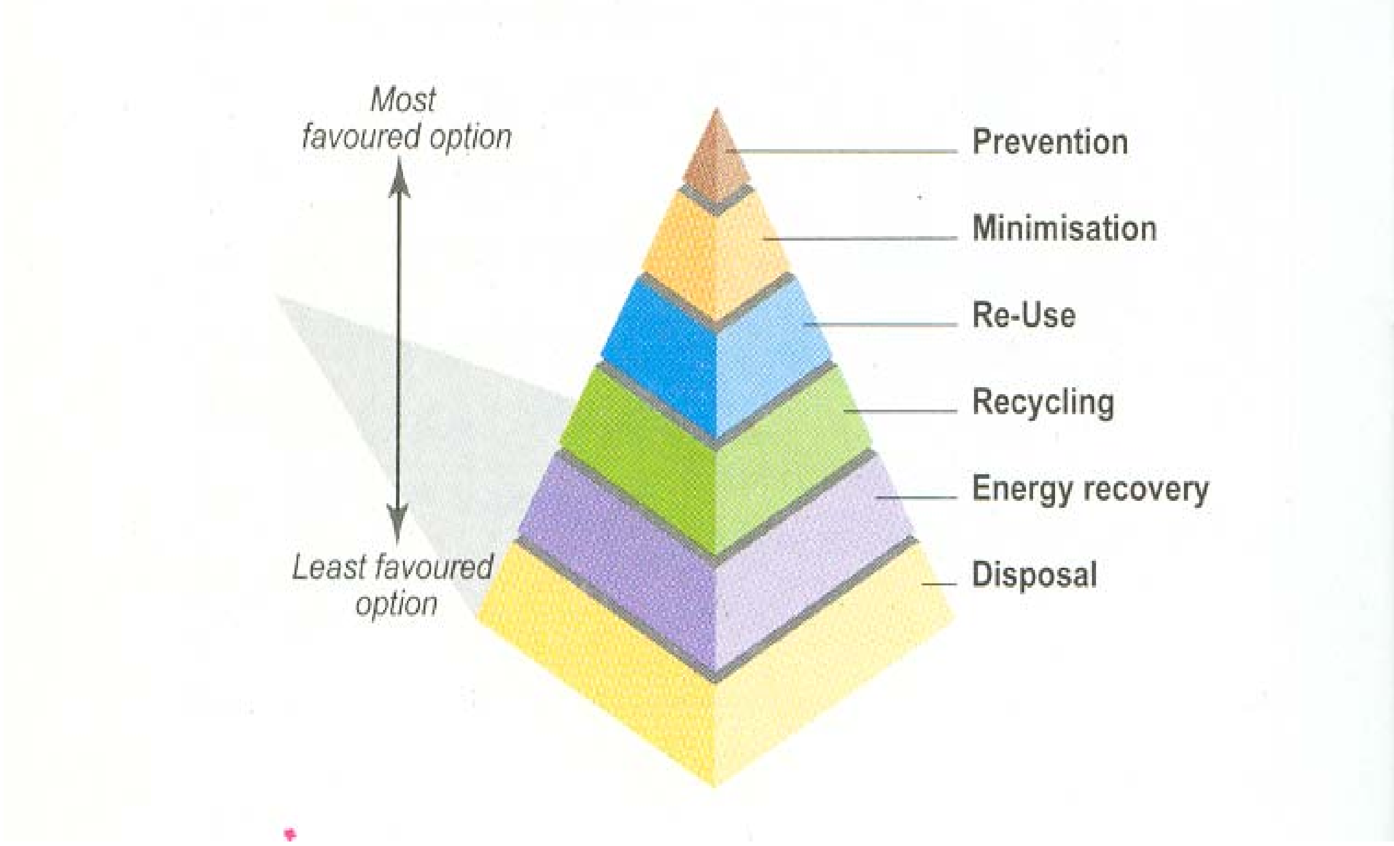


Fig. 2 Spatial structure of the dioxin molecule

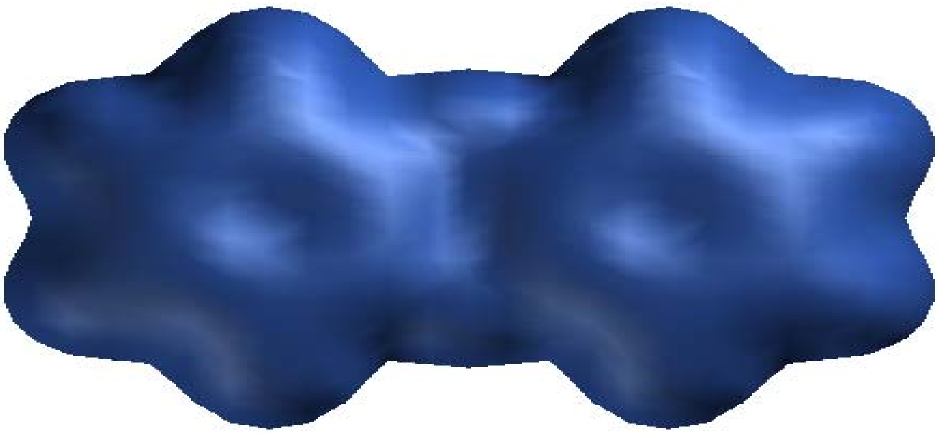
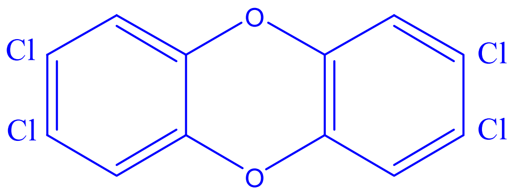


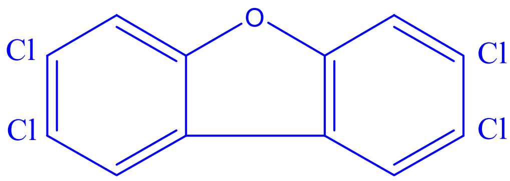
Fig. 3 Dioxins:molecular structures

Dioxin



2,3,7,8-TCDD

Furan



2,3,7,8-TCDF

(This lecture was delivered at the UCC Science Faculty Public Lecture Series 2002-2003, on November 27, 2002.)