Coalition for Responsible Waste Incineration

"The Role of Incineration In Integrated Waste Management - The Total Story"*

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ABSTRACT

Proper management of the wastes generated by our modern society is a challenge confronting America. It is generally agreed by those knowledgeable in waste management that "Integrated Waste Management" which encompasses source reduction, recycling, incineration, and landfilling is the approach we should take in safely managing our waste. While we have to change our "throw away" society through source reduction and recycling to conserve our limited resources, it is unrealistic to expect the elimination of all waste in the future. We will still have to manage the waste which remains.

Although it is highly desirable to eliminate any pollutant emissions, we have to realize that pollutant emissions occur not only during industrial operations (which include source reduction, recycling, and composing); they also occur in

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routine human activities as well as in natural processes. We must appreciate that no technology (including source reduction and recycling operations) is risk free, nor are any human activities. However, with proper engineering, design, and operation, many technologies (which include incineration and landfilling) can be safely and effectively employed. We should not point our fingers at selected targets and demand zero emission without considering if the pollutants have already been reduced to a point of little concern.

Risk assessment is a useful tool in helping our decision making to wisely use our limited resource to address the multitude of problems with which our society has to deal. However, due to the many misinterpretations on the significance of risk assessment, the public is confused about the incineration operation. This paper tries to put the issue into a proper and balanced perspective.

INTRODUCTION - OUR WASTE DISPOSAL PROBLEM AND INTEGRATED WASTE MANAGEMENT SYSTEM.

> "As a nation, we generated about 160 million tons of solid waste last year; by the year 2000, we are projected to generate 190 million tons. . . . This deluge of garbage is growing steadily and we must find ways to manage it safely and effectively. Eighty percent of garbage is landfilled. But we're running out of space to bury it in existing landfills; more than one third of the nation's landfills will be full within the next few years and many cities are unable to find enough acceptable sites for new landfills or new combustors."
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> "The report recommends using 'integrated waste management' systems to solve waste generation and management problems at the local, regional, and national levels. In this holistic approach, systems are designed so that some or all of the four waste management options (source reduction, recycling, combustion and landfills) are used as a complement to one another to safely and efficiently manage municipal solid waste. . . . A key element of integrated waste management is the hierarchy, which favors source reduction (including reuse) to first decrease the volume and toxicity and increase the useful life of <u>products</u> in order to reduce the volume and toxicity of <u>waste</u>. Recycling (including composting) is the preferred waste management option to further reduce potential risks to human health and the environment, divert waste from landfills and combustors, conserve energy, and slow the depletion of nonrenewable natural resources. In implementing source reduction and recycling, we must avoid shifting risks from one medium to another (e.g., groundwater to air) or from one population to another. Landfills and combustors will be necessary for the foreseeable future to handle a significant portion of wastes, but are lower on the hierarchy because of the potential risks to human health and the environment and long-term management costs. This risk potential can be largely minimized through proper design and management."

The above two paragraphs are quoted from "THE SOLID WASTE DILEMMA: AN AGENDA FOR ACTION," which was prepared by the U.S. Environmental Protection Agency, Office of Solid Waste in February 1989 (1). It summarizes our waste disposal problem and the realistic approach we, as a nation, should take in solving the problem which each of us contributed directly. It also discusses the priority of the four waste management methods.

RECYCLING ALONE CANNOT SOLVE OUR WASTE MANAGEMENT PROBLEM; AND RECYCLING ALSO POSES SAFETY, HEALTH, AND ENVIRONMENTAL RISKS.

The following quotation by Dr. Winston Porter is a good summary on the realistic meaning of recycling operation. Dr. Porter is the former Assistant Administrator of the U.S. Environmental Protection Agency with responsibility for solid and hazardous waste management (2).

> "EPA set a national goal of recycling 25% of our solid waste by 1992. But going much above the 25% rate would require tremendous infusions of capital and technology that might well be spent more beneficially on other social problems. To get in 50% recycling range, we must deal with such multi-material items as blenders, toasters and bicycle pumps, which are very costly to recycle. To aim for unrealistic recycling rates would not only discourage the public, but might lead to a fool's paradise where landfills and water-to-energy facilities are sacrificed on the altar of pie-in-the-sky goals."

Recycling aluminum is a good example of success which not only saves energy, but also alleviates risks posed by primary processing of virgin material. Cans made of "pure" aluminum are easy to recycle. However, recycling of most other material will not be as easy. Containers contaminated by food waste and "multi-material" products are of little economic value. Even with source separation at each individual household into metals, glass, paper and plastics, the recyclable material is still quite mixed. The materials are separated in part by handpicking in a separation plant which is typically noisy and dirty due to the nature of garbage. This causes safety and health risks to the workers. Respiratory ailments (smarting eyes, fatigue, and occasional nausea) were recorded for workers at Danish sorting plants due to bacteria and fungi contaminations (3).

Also, unless there are markets for the recyclable materials, we have not actually recycled them. The multi-material may be recycled to produce low-grade products. However, the market for the low-grade product is limited. Considering the citation of initial successful stories of recycling in a few small communities and to expect that those 84% recycling rates (4) can be realized on a larger scale is simply unrealistic. Also, a fraction of the 84% collected recycling-material is disposed of as waste in the various recycling processes and is not truly recycled.

As pointed out by Visalli (5), it should be clear that all methods of processing solid waste result in process emissions and effluents, and in ash or sludge residues that have potentially hazardous compounds. We can spend lots of money, consume additional energy, use certain special chemicals to separate those multi-material items into a useable form. Before we do that, we need to consider: Is energy a resource? Will combustion generated pollutants be emitted during the energy production process? Will the special chemicals used in the separation process become another waste which has to be disposed of? What is the impact of each source reduction and recycling operation from an overall environmental, safety, and health point of view? These are the same questions we have been raising about incineration and landfilling.

Paper without inert ingredients (newspaper, computer paper, cardboard) and certain plastics can be recycled a few times. Eventually, chemical bonds in such organic materials will become weak and the materials become brittle. Then, the materials will become useless. At that point, they can then be burned to recover energy which is another valuable resource which we should conserve.

LANDFILL WILL BE NEEDED IN THE FUTURE

Landfills will remain a necessary component of any solid waste management plan. Municipal solid waste landfills will be needed to manage recycling and incineration residues as well as the non-recyclable and non-combustible segments of the waste stream. Modern landfills are designed to protect groundwater quality and not harm the environment.

WHAT IS INCINERATION? - PUTTING IT INTO PERSPECTIVE

Oxidation is one type of chemical reaction between oxygen and other material with the release of energy or heat. Many reactions surrounding us are oxidation processes such as biodegradation, composting, and animal metabolism. If the oxidation reaction is extremely fast and occurs with the release of light and large amounts of heat, the process is called "combustion." If the material burned is a waste, the combustion process is called "incineration." From the chemical reaction point of view, they are all oxidation processes and they all produce various Products of Incomplete Oxidation.

Municipal waste incineration as we know it today began a little over 100 years ago. Today, there are 168 plants in operation in the U.S. (6). Prior to 1970, incineration was associated with the scene of black smoke and the release of odorous gases. Because of these concerns, many people perceive that there must be inherent problems with waste incineration. Due to technology and science advances and improved environmental awareness, today's incinerators are quite different. They are designed for effective combustion and are equipped with proper pollution control equipment to reduce the emission of pollutants to very low levels.

Incineration plays an important role in pollution prevention after recycling and resource reduction. It permanently eliminates toxic organics or organics which may cause future environmental concerns. Incineration reduces the volume of trash by 90% and conserves the ever scarce landfill space. In addition, it can produce electricity and reduce the consumption of fossil fuel.

POLLUTANT EMISSIONS - A NATURAL AND UNIVERSAL PHENOMENA

Some people consider any man-made "pollutant" emission immoral and should be stopped. This is an oversimplification of natural processes and the world in which we live. All human, natural, and industrial activities emit or produce pollutants. An in-depth qualitative and quantitative discussion of both natural and anthropogenic (man-produced) pollutants can be found in Prof. Thad Godish's book, "Air Quality" (7). In addition to discussion of the sources of pollutants, the book also gives a good discussion on the fate for various pollutants.

Natural processes contribute a very large portion of all pollutants: volcanoes, forest fires, decomposition of plants and animals, soil erosion, dust storms, pollen and mold spores, ocean spray, volatile organic compounds (VOC) emitted by vegetation, ozone from electrical storms, stratospheric intrusion, photochemical reactions, etc. We do not live in a world which is free of pollutants.

Anthropogenic air pollution has been and continues to be viewed as a serious problem. Its seriousness lies in the fact that high, potentially harmful pollutant levels can be produced in environments where harm to human health and welfare is the most likely. We can and should control those emissions. However, to totally eliminate all of them is simply unrealistic.

Sources of anthropogenic pollutants include just about any human activity: automobiles, trains, airplanes, open burning, residential wood burning, utility power plant combustion, commercial/institutional fuel combustion, incineration, evaporative losses from gasoline marketing, evaporative losses from organic solvent consumption, unpaved roads, wastewater treatment unit VOC emissions, fugitive emissions from synthetic organic chemical manufacturing, process emissions from bakeries, crude oil and natural gas production, asphalt paving operation, use of hair spray or household cleansers, etc. An estimate of the total national emission of each source in the U.S. can be found in References (8) and (9).

Studies have found that pollutant concentration levels indoors (e.g., residences, public buildings, offices) are sometimes higher than in heavily polluted urban or industrial area outdoor air (10). Sources of indoor pollution include activities of the building's occupants such as cooking, cleaning, smoking, hobbies, use of appliances and tools; materials used in the construction of buildings and furnishings; geologic materials around the building; and influx of polluted outdoor air.

As shown in Table 1, incinerator emissions (a subpart of Industrial Combustion) are only a very small fraction of the host of pollutants in the environment from other combustion sources (11). Nearly 65% of combustion VOC (volatile organic compounds or referred to as PIC, Products of Incomplete Combustion from incineration) emissions are from transportation sources, and more than 25% are from commercial and residential combustion (principally wood combustion in wood stove and fireplaces).

TABLE 1: U.S. 1985 nationwide emissions from combustion sources and total anthropogenic emissions (thousand tons).

Major Category	SO_2	NO_x	VOC	PM	CO
Utility Combustion	15,590	6,659	58	490	367
Transportation	864	8,834	7,350	4,428	42,697
Industrial Combustion	3,729	2,358	375	635	2,359
(Incinerators)	(376)	(23)	(27)	(11)	(58)
Commercial/Residential Combustion	571	689	3,037	1,529	8,899
Other Combustion	572	712	591	715	4,360
TOTAL COMBUSTION	21,326	19,252	11,411	7,797	58,682
TOTAL ANTHROPOGENIC EMISSIONS	22,404	20,505	22,387	36,913	63,375

Notes. SO_2: Sulfur Dioxide NO_x:Nitrogen Oxides
VOC: Volatile Organic Compounds or Products of Incomplete Combustion (PICs) for combustion sources.
PM: Particulate matter. CO: Carbon monoxide

Biodegradation (degradation of organic materials by microorganisms) is a slow oxidation process. The final products are mainly CO_2 and water just like in incineration. In addition, many organic by-products (Products of Incomplete Biodegradation) and cell biomass are produced. Methane gas is one of the most important by-products. Dragun in his book "The Soil Chemistry of Hazardous Materials," compiled a list of 350 compounds which have been identified in natural soil from biodegradation of plants and dead animals (12). Those compounds are typically in the 1-5 ppm (parts-per-million) range in soil. If studies had been conducted to look for compounds in the ppb (parts-per-billion) range as was typically done in incinerator flue gas, many more compounds would be found.

Composting is a biodegradation process. Actually, to make composting work at a reasonable rate, one has to turn over the compost pile frequently, or pass adequate air through the pile to provide adequate oxygen and to get rid of the toxic gases generated in the composting process. Otherwise, the biomass cannot survive and its growth is inhibited. A large amount of landfill gas is produced from biodegradation of landfilled materials (13). If non-yard waste is composted, toxic metal contamination can be a concern in the final use of the product. Composting carries risks just like any other management methods.

Formaldehyde, a carcinogenic and mutagenic product of incomplete oxidation, is not only found in combustion flue gas, but is also a product of biodegradation and animal metabolism. Normal human blood contains 3 ppm. Formaldehyde is also present in many common foods such as beer and wine (14).

Emission of toxic metals from incinerators is another concern. Incineration neither generates nor destroys toxic metals. Table 2 is a comparison of carcinogen metals (arsenic, beryllium, cadmium, and chromium) and lead found in the native soil (12), in ambient air (15), and the maximum allowable increase at the maximum ground level impact point such that the air pollution control device of a hazardous waste incinerator must be able to achieve (16). It can be seen that we do not live in a world free of toxic metals either.

TABLE 2: Comparison of toxic metals in native soil, ambient air, and allowed incremental level to Maximum Exposed Individual.

	Native Soil (micrograms/gram)		Ambient Air (nanograms/m^3)			MEI Limit (nano-g/m^3)
	Typical	Extreme	Remote	Rural	Urban	Max Ground Increment*
Arsenic	1-40	0.1-500	0.007-1.9	1-28	2-2320	2.3
Beryllium	0.1-40	0.1-100	?	?	?	4.2
Cadmium	0.01-7	0.01-45	0.003-1.1	0.4-1000	0.2-7000	5.6
Lead	2-200	0.1-3000	0.007-64	2-1700	30-96270	90.
Chromium	5-3000	0.5-10000	0.005-11.2	1.1-44	2.2-124	0.83**

* Maximum allowable. Actual contribution must be less than these numbers.
** The maximum incremental ground concentration is for Chromium (VI) only.

PUBLIC CONCERNS RELATED TO INCINERATOR EMISSIONS

Because of wide variation in municipal solid waste components, there are many types of pollutants that can be emitted from a garbage incinerator. As the result, the number and amount of pollutants from a garbage combustor (in which the emissions must be controlled by modern air pollution control equipment) are far more than that of conventional fossil fuel-based systems, such as coal-fired boilers and oil-fired heaters.

(a) Concern on emission of trace organics or products of incomplete combustion

As discussed previously, incineration is only a very small part of the many combustion sources. While many other combustion sources are not designed for maximum combustion efficiency, modern incinerators are required by law to be designed, operated and continuously monitored for assured good combustion efficiency (17). As a result, very little unburned organics remain in the stack flue gas.

Extensive studies have been conducted on PICs from different combustion sources which include auto engines, fireplaces, apartment boilers and barbecue grills (18). In general, the majority of the PIC compounds are partially oxidized organics. A fraction of those compounds are polynuclear aromatic hydrocarbons (PAHs) which are suspected human carcinogens. The important point is that with proper engineering and operation, modern incinerators emit very little organics and contribute very little of those PAHs.

There is also concern about the large number of unknown and unidentifiable compounds in flue gas due to incomplete combustion. The important point here is that scientists have studied incineration emissions in great detail. Compounds emitted from a good combustion source are very low and are typically in the parts-per-billion (that is equivalent to one second in 32 years) or less range. If we look for anything else in this world to that level, we will find hundreds of unknown compounds in just about anything, including any food we eat and the beverage we drink (19).

Bioassay testing is a useful tool to screen mutagens (which are related to carcinogens) and to compare PIC emission from different combustion sources. Bioassay tests have found that organic emissions from all combustion sources are mutagenic. The extent of mutagenicity is mainly a function of combustion efficiency (20). PIC emissions from small combustion sources which in general do not have good combustion control and are not designed for maximum combustion efficiency (such as wood stoves) tend to be more mutagenic. Emissions from large combustion devices tend to be much less mutagenic because large combustion sources generally are designed and operated for better combustion efficiency. Hence, the real concern about the toxicity of organic emission from combustion sources should be focused on combustion efficiency, rather than on whether the combustion source is a waste incinerator. We should be more concerned about automobile exhaust gas and fireplace flue gas which are produced by poor combustion devices.

There is concern that nitrogen oxides and polynuclear aromatic hydrocarbons emitted from incinerators under ambient conditions will produce mutagenic species, peroxyacylnitrate (PAN) (4). To be fair, one should point out that it is automobile exhaust gas which contributes to the majority of the PAN production problem (7).

(b) Toxic metal emission and acid gas.

Another concern is the emission of toxic metals from incinerator flue gas. Under high temperature combustion conditions, toxic metals may be volatilized. As the combustion vapor cools down in the pollution control device, very fine particulates may be formed. The removal of very fine particulate is a costly operation and requires specially engineered equipment. Very fine particles are more readily absorbed in the lungs through inhalation and can be harmful to human health if the emission is not controlled.

We need to put this issue into proper perspective. Almost all combustion sources, including power plants, have the potential of emitting fine particulate toxic metals and this is not just limited to incineration. The issue here should be what type of pollution control device needs to be installed to control the emission to a level which will not present a threat to human health and environment. As required by law, modern incinerators are equipped with proper pollution control equipment (17).

Just like any other combustion sources and some natural biodegradation processes, incineration produces acid gas as well. Again, the important issue is what appropriate pollution control device should be installed to remove those acid gases from flue gas.

DIOXIN ISSUE - PUTTING IT INTO A PROPER PERSPECTIVE

Emission of dioxins and furans from municipal solid waste incinerators is a key concern to many people. Based on demonstrated effects in animals, some dioxins are extremely toxic to certain animals and are probable human carcinogens. Small amounts of these chemicals cause different toxic responses in different animals; current information about the impact on human health is inconclusive (21). For example, the dose necessary to kill a guinea pig (22). After many year's research, there is growing feeling among scientists that the extent of the hazard to humans of the very low level dioxins in the environment may be overstated.

Dioxins are also found as unwanted trace by-products from chemical processes which involve chlorinated products such as Agent Orange, and 2,4,5-D pesticide; or in the bleaching of paper pulp (21, 22). Organic chemical reactions are extremely complex and any reactions will produce a large number of trace organics in the parts-per-million or parts-per-billion ranges. This is a fact known by any organic chemist.

Since combustion is a chemical process, emission of dioxins and furans are found in almost every combustion process which includes discharges from automobile emissions, forest fires, cigarette smoking, residential wood burning, metal processing and treatment plants, pulp and paper mills, copper smelting plants, and waste incinerators (22) (23). The level of dioxins measured in very low and is typically in the parts-per-trillion range (that is like looking for one second in 32,000 years). It can be expected that many source reduction and recycling operations would generate dioxin as unwanted trace by-products as well.

Data from 36 municipal solid waste combustion facilities, both old and new, in the U.S., Canada, Japan, and Europe indicate six orders of magnitude of variation in stack gas concentrations from the lowest to the highest value (that is, if the lowest level measured is one, the highest level measured is 1,000,000) (24) (25). New incinerators typically emit less. This indicates that there is big room for improvement in the design and operation of a garbage incinerator. The newer generation incinerators are designed and operated to minimize the emission level to very low as mandated by law (17).

A comprehensive performance study conducted by the Environment Canada (the counter part of US EPA in Canada) at a garbage incinerator found that the total amount of dioxin and furans released from the stack is less than the total amount which already existed in the garbage feeds (26). This shows that if an incinerator is designed and operated properly, there is a net decrease of dioxins in our environment.

Many dioxin-related studies were conducted in the past fifteen years. A good summary review of these vast amounts of information was done by Travis of the Office of Risk Analysis, Health and Safety Research Division, Oak Ridge National Laboratory (27). Studies have shown that emission from well-designed and well-operated modern garbage incinerators contribute little (1% or less) to the background dioxin level in our environment (27) (28).

CANCER, PUTTING IT INTO A PROPER PERSPECTIVE

The two major reasons for cancer are aging and diet. As we live longer (which we do) due to improvement in our living conditions, more people will die of cancer due to aging alone.

One out of four people eventually die of cancer. However, when the trends are adjusted for the increased size of the population and for changes in age distribution, the total cancer mortality rate from 1962 to 1982 has increased 8.7%. There was an enormous increase in the incidence of lung cancer (more than 200%) and a marked decrease in stomach cancer during the past 35 years. If lung cancer is excluded, the 8% increase in mortality becomes a 13% decrease. Lung cancer is generally considered to result primarily from smoking cigarettes (29).

This epidemiological data indicate that inhalation, rather than digestion, is more of a threat for "increased" cancer incidence in the past 35 years. Hence, the inhalation route has been the focus of many risk assessments.

Human diet contains a great variety of natural mutagens and carcinogens. Plants contain natural pesticides to protect themselves against insects. We are ingesting in our diet at least 10,000 times more by weight of natural pesticides than of man-made pesticide residues (14). The combined effects of alcohol, diet, and smoking are related to 70% of U.S. cancer deaths (30). While we try hard to minimize emission of man-made carcinogens, we also need to appreciate that we do not live in a world which is free of cancer causing material. We must put into proper perspective of the very low upper-bound cancer risk posed by the modern, well-designed and operated incinerators.

RISK ASSESSMENT AS A TOOL TO SET PRIORITY FOR BETTER USE OF OUR RESOURCES ON REAL POTENTIAL ENVIRONMENTAL PROBLEMS

Since there are so many natural and man-made pollutant emission sources, we need to identify those real risk issues and separate them from perceived risk items. The perceived risk can be highly misleading (31). People tend to perceive an event as highly risky if they are unfamiliar with or have no control over the event. Risk assessment methodology is developed to address this problem. Risk management steps are then developed to minimize the risks to an acceptable level. (32) (33)

The following quotation provides the best description of what is a risk assessment: (33)

> "Although quantitative risk assessment has become an important part of this analysis, its use as basis for implementing environmental policy remains controversial. This is so because quantitative risk assessment is the product of what former EPA administrator William Ruckelshaus has called "a shotgun wedding between science and the law."
>
> "Risk assessments governed by guidelines only provide for consistency and orderly decision-making. They do not give certainty in the

> scientific sense, nor can they be used to establish PRECISE numbers of persons who will be stricken with some disease. Quantification is useful in risk assessment to approximate the magnitude of an effect, to set priorities, or to make comparisons."

Unfortunately, many people mistakenly think that risk assessment projects either actual or approximate risks. Due to this misconception, many consider that any additional (true) risk to human life is immoral and unacceptable.

If the concern is on emission, the best way to understand the meaning is not to look at those risk numbers. The best way may be to compare emissions with background levels or to compare them with emissions from other sources. The Total Human Exposure risk assessment approach which considers pollutants from all sources and considers all exposure routes, is a more reasonable method to pinpoint true environmental problem areas which require our attention (34). The Total Human Exposure field studies conducted by the US EPA have found many surprises about the relative contribution of various pollutant sources to public health risk. Traditional sources (stacks, toxic waste sites, etc.) may not be the key contributor.

UNCERTAINTY PROBLEM IN RISK ESTIMATE AND THE UPPER-BOUND RISK ASSESSMENT

Risk assessment consists of four major steps: Hazard assessment, Dose-response assessment, Exposure assessment, and Risk characterization. Each major step consists of several small steps. Due to limitations in scientific understanding, data, models, and methods, virtually all risk assessments are characterized by substantial uncertainties (30) (35)

In order to handle this uncertainty problem in conducting risk assessment, conservative assumptions or safety factors are used at each step to provide an ample margin of safety to protect public health or to prevent a potential adverse environmental effect.

For example, in determining the dose-response relationship for human health impact, it is typically done through animal bioassay tests. In conducting animal bioassay tests, high exposure levels at or approaching the maximum tolerated dose before the test animal is killed, are employed. It was found that if the dosage is reduced by half, two-thirds of a group of 52 chemicals judged by National Toxic Program as carcinogens will not be classified as carcinogens (29). It can be expected that if the tests were conducted at the very low dosage which we would experience in a real world situation (may be 1,000,000 times or more lower than those used in the animal tests), none of them may be classified as carcinogens. In order to be protective, U.S. regulatory policy adopts the concept that there is no safe level below which carcinogens will not have an effect.

In making the worst case assumption, many assumptions are unrealistic in order to be protective. In one argument against incineration risk assessment, the assumption of all particulates remaining in suspension was criticized as being against physical law (4). The argument fails to understand that the assumption is made as the worst case to be protective. To be cautious, when conducting inhalation-exposure-route risk assessment (as is the case for most work done) one will assume that no particle will settle so that all particles would be inhaled by humans. On the other hand, in conducting ingestion risk assessment, one is more likely to assume that all particles will settle such that the maximum amount would be ingested. Several particulate deposition models were used for many non-inhalation-exposure-route risk assessments (36).

In conducting exposure assessment, MEI (Maximum Exposed Individual) is commonly used. MEI is an imaginary individual who stays in the same spot (which is the maximum ground level impact point from the stack flue gas) continuously for 70 years. He stays outdoors all his life since the impact of incinerator emission on indoor air would be lower. All pollutants he inhales is absorbed by his lungs at 100% efficiency and those pollutants remain in his body all his life and do not discharge with human wastes. There is a series of safety factors built into this assessment. Those factors multiply at each step. Even though the safety factors for each individual steps may be small (such as 10, 5, 10, and 2 at each step), the overall safety factor becomes enormous (1,000 in this case) which make it highly protective.

The repeated use of exceedingly unlikely exposure scenarios makes it difficult to compare assessments by different scientists because they incorporate widely varying levels of conservatism in their assumptions. Also, since there are so many possible assumptions to make, some may be considered conservative, and some may be considered not so conservative. This is a very complex issue. However, overall, it is agreed by those who are familiar with risk assessment methodology and the meaning of those assumptions that conservatism outweighs non-conservatism (37).

Environmental risk estimates are described as upper-bound estimates with the real risks judged to be between the upper-bound values and zero (no risk at all) (37). The meaning of the upper-bound risk estimate can be best explained by an example given by Dr. Fred Hoerger (38).

He concluded that "It can be said that the upper-bound estimate of rainfall for the United States is 15,000 inches per year. Historical records show the highest single-day rainfall was 43 inches in Alvin, Texas, in 1979. Simply multiplying this number by the number of days in a year and extending it to the entire United States gives my estimate of 15,000 inches (1,250 feet)

Since we know as a fact that it does not rain everyday of the year, a more realistic person may argue that a more reasonable upper-bound assumption is to assume there are 100 rainy days which is conservative enough. The upper-bound estimate is reduced to 4,300 (43 times 100) inches.

On the other hand, a conservative person may argue that the estimate is not protective enough since the highest one-hour data ever recorded in XYZ town was 10 inches. Multiplying that by the total hours in a year and extending it to the entire United States will produce a worst case estimate of 86,400 inches (7,200 feet).

In addition, the conservative person may argue that we have not considered all possible routes. One example is dew on the ground as moisture condensation which occurs every night. We need to add another one inch to the estimate. The correct number for the upper-bound, conservative projection of U.S. rainfall should be 86,401 inches.

One may argue that this is ridiculously protective, since yearly rainfall in the United States averages from a few inches to perhaps 50-60 inches per year in Miami, Florida. The estimate of 86,401 inches for U.S. rainfall is outrageous, and the real conservative number cannot be higher than 60 inches for the entire United states. Unfortunately, in the environmental risk assessment, we do not have definitive data to tell us how ridiculous the upper-bound risk estimate is. But, keep in mind, risk assessment is not intended to set a definite number. Rather, it is intended to get a conservative estimate for risk potential to help decision-making purposes.

For example, if the concern about rainfall is to assess the possibility of flooding when building a house at the top of a 1,000 foot mountain, it does not matter what is the true rain fall as long as a reasonable worst case estimate is less than 1,000 feet and we can conclude that flooding caused by rainfall is not likely a concern. We may then want to focus our resources to other more important issues such as: Do we have enough money to build the house? How is the road condition leading to the construction site? How is the school district and community, etc.? If we concentrate our effort in arguing whether we should use maximum one-hour rainfall data for worst case rainfall estimate, or in arguing whether we have considered all possible routes such as adding another one inch from dew caused by moisture condensation, we are missing the big picture.

Some have criticized current risk assessment as being conducted to reach a target number instead of conducting an unbiased risk assessment (4). One needs to realize that the issue is not whether everyone comes up with the same one in one million risk number. The issue is "Are all the assumptions reasonably protective? Are all those comparisons done in a somewhat consistent way?" Focusing only on the risk number produced is not the goal of risk assessment for upper-bound estimate. In our rainfall estimate example, one may want to adjust those conservative assumptions a little (as long as they are still conservative) so that one can be more confident to make the statement that the upper-bound rainfall is less than 12,000 inches which is the level of concern. Whether the true rainfall should be 60 inches or 12,000 inches is not the issue here.

An analysis of 21 risk assessments conducted at 21 proposed municipal waste incinerators in the U.S. can be found in Reference 36. The analysis provides a fair and knowledgeable professional evaluation on the risk assessment work conducted. The authors suggested that the total risk is overestimated by the repeated use of conservative assumptions. The assessments typically found higher upper-bound risks from non-inhalation exposure routes than inhalation route. However, both routes pose very low risks due to the fact that pollutants emission from modern incinerators which comply with the regulations are very low.

RISK COMPARISON AND RISK DECISION PROCESS

Communication of risk information among lay people, technical experts, and decision-makers is a difficult task and people are still struggling to find a good way to do it right (39). The public's response to these risk assessments swings from apathy to panic, depending on the latest newscast. This is made even more difficult by the many misinterpretations on the significance of those risk numbers.

In general, an incremental risk of one in 100,000 to one in 1,000,000 is considered as acceptable in various risk assessment for regulatory decision making purposes. To explain the one in 100,000 upper-bound risk number, let us assume that we are in a city of 100,000 people. Of these 100,000 people, 25,000 will probably contract cancer, regardless of where they live, what water they drink, or to what emissions they are exposed. If all 100,000 people are exposed to the same MEI industrial emissions (that is, all 100,000 people stay at the same point of maximum ground impact concentration for 70 years and never leave that point), there is a possibility that one additional cancer case "may" develop. Or, 25,001 people may contract cancer. If there are errors in the estimations, they are on the side of caution and extra safety to take care of uncertainties.

In order to help public understanding of those risk numbers, risk comparison is frequently utilized. For example, the one in 100,000 cancer risk is equivalent to the risk to a person who smokes one cigarette in a life time, to a person crossing the street one time, or to the possibility of a person being struck by lightning (30).

It was stated that the comparison of the very soft number of incinerator risks with the hard number of smoking risks to show how low the risks from modern incinerator emission are, is inappropriate (4). This is a good point but for just the opposite reason. This type of comparison will confuse the public since the cancer risk from cigarette smoking is from statistical data of actual human lung cancer deaths. On the other hand, cancer risk estimated from incinerator emission is based on many unrealistic worst case assumptions and is an upper-bound number (30) (40). The real risk for the incinerator emission is less than that number, and is most likely approaching zero.

We all accept risks every day. When we accept these voluntarily, we don't worry. Problems arise when the risks are forced upon us. An involuntary exposure that increases the risk of cancer or birth defects is perceived as a physical and moral insult regardless of whether the increase is small or whether the increase is smaller than risk from other exposures. Unfortunately, human beings never live in a risk-free world and all human activities (which include source reduction and recycling activities) carry risks. How to effectively communicate the risk concept to the public is still a challenge to us.

RISK MANAGEMENT TO MINIMIZE RISK

Risk management deals with the need for risk reduction. The following are some of the issues on which we should spend more effort, in a constructive way, to further reduce the already low risks posed by modern, well-designed and operated incinerators..

- Continue to improve incinerator design and operation.
- Continue to improve air pollution control system design and operation.
- Continue to improve operator training program.
- Continue to improve continuous emission monitoring system.
- Continued research to support the above activities.
- Continued source reduction program to minimize the amount of toxic metals which have to be sent to incinerator.
- Continued recycling program to minimize the amount of waste which have to be disposed of in the incinerator.
- Reasonable emission standards to regulate pollutants emitted from incinerators.

For example, the concern over continued reliability on incinerator organics destruction performance can be assured by continuously monitoring the flue gas CO level. Carbon monoxide is a stable product of incomplete combustion; therefore, keeping the level of carbon monoxide in the flue gas low assures that the incinerator is operating efficiently.

We need to realize that no technology (including source reduction and recycling operations) is risk free, nor any human activity. However, with proper engineering, design, and operation, many technologies can be safely and effectively employed.

OTHER ISSUES

(a) Potential unfair high risk to local community next to an incinerator.

Again, we should look at the total picture rather than deal with the issue as a perceived problem. We should evaluate the contribution of emissions from modern incinerators equipped with proper air pollution control equipment and compare that with local background ambient air pollutants, worker exposure, indoor air pollution, pollutants in drinking water, pesticide residues on food, chemicals in consumer products, etc. Then we can make a fair statement whether there are truly undue risks to the local community, or they are only perceived risks.

The potential of higher impact to local population from the very low level emission of a modern incinerator can be further minimized through dispersion from a tall stack (typically diluted by 100,000 times at maximum ground impact point) so that the impact will be very close to the background level from many natural and man-made pollutant emission sources.

(b) Overall ecological impact and risks.

Combustion is an ultimate recycling process to convert waste back to useful elements, C02 and water, for vegetation use which forms a complete natural carbon cycle. This is similar to the natural biodegradation process but at a much faster rate with much reduced emission of potentially toxic organic intermediates.

People are concerned about greenhouse effect and global warming. We need to realize that the contribution of incineration to the total combustion sources is small. After all, biodegradation of the waste material in a landfill produces both methane and CO_2 (roughly half of each), and methane is a much worse greenhouse gas.

ENGINEER AND SCIENTIST'S NEW RESPONSIBILITY IN A CHANGING SOCIETY

NIMBY - "Not In My Backyard" is a problem we have to deal with in choosing a site for any waste management facility. There are obvious reasons for NIMBY: reduction of property values, social status, concern over health, and a focal point for neighborhood and citizen activism, plus public fear and uncertainty about the waste management facility.

In dealing with this issue, we should also consider whether modern resource recovery facilities are necessary and are safe. Too often, the real issue gets lost in the bright picture and slogans shouted on the TV screen.

Until recently, industry has traditionally ignored the need to get local residents involved in decision-making related to technology issues. Too many scientists and engineers believe that the public does not understand those issues and need not be involved. The technical community will have to realize that today's public is better educated and more knowledgeable. In the past few years, industry started to realize this culture change and started to respond. One example is "Responsible Care" which is chemical industry's initiative to improve performance in response to public concerns about the impact of chemicals on health, safety, and environmental quality. More and more, the public is involved in the decision-making process for issues related to environmental protection. Engineers and scientists have to make an earnest, sustained effort in communicating with the public about the risks and benefits inherent in technology, particularly technology that involves public policy.

CONCLUSIONS

Our garbage management problem is a real problem. We should not wait until garbage begins to pile in the streets to take the first step to be more realistic. It is not enough to "Just say no." We have to offer a constructive and realistic alternative.

In looking for solutions, we should consider overall safety, health, and environmental protection. We have to take responsibility for solutions we propose and to evaluate whether they are really workable. We have to consider "the total story" in making our judgement.

The key to solving our waste management problem is to take an integrated approach: produce less waste, recycle more, burn what cannot be recycled to recover the energy content, and dump only ashes and non-combustibles in properly designed landfills.

We should utilize our available financial resources wisely to deal with real environmental risks rather than perceived problems. Although people do not like to talk cost in issues related to environmental protection, cost is a real thing which we all will eventually pay for either in the form of taxes or higher consumer prices. We should consider Total Human Exposure from all sources and all routes. And, we should not just point our fingers at selected targets and unrealistically demand zero pollutant emission without considering if the pollutants have already been reduced to a point of little concern. We have to realize that every activity has a point of diminishing return.

As pointed out by Prof. Connett (4), "We need a comprehensive analysis of all the different strategies for solving the trash crisis. It is not enough to opt for one solution, and then set out to 'prove' that it is safe." This same statement must also apply to those people who claim that source reduction and recycling alone can solve our trash crisis. Locally on a very small scale, this may be workable at surface; globally, it is unrealistic. Even on a small scale, not all collected materials are truly recycled at the recycling plants.

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