Municipal Solid Waste Composting:
Issues in Risk Assessment & Management/Work Health & Safety
Fact Sheet 5 of 7

James W. Gillett
Institute for Comparative & Environmental Toxicology
Cornell University

What are the risks in various alternatives for resource recovery and waste management? Who or what is threatened? What is saved or protected? Decisions about environmental risks are made in the face of uncertainties beyond common experience, particularly for new technologies. Municipal solid waste (MSW) composting lacks evaluative data offering a foundation on which to base scientific assessments. With MSW composting, the situation is further complicated by the highly diverse, and often changing, nature of MSW and other materials with which it might be composted.

Historically, composting has both provided a soil conditioner/nutrient source and been a means of waste management of large volumes of sludge and manure. The product can be a clean, odor-free, and welcome garden amendment, but the process may be messy, odiferous and subject to many complaints, even though people recognize it as a "green" alternative to landfills and incinerators. This obvious ambivalence affects the policies and perceptions regarding composting and its products.

Serious, immediate and wide-spread threats to the environment and consumers presented by MSW composts are not evident. Specific hazards to workers are recognized and being addressed, although there are concerns (see below). Most of the unresolved issues focus on long-term, chronic exposures. Despite uncertainties, those responsible for risk management must act to safeguard public health and the environment. Reasonable regulations must be set and standards for accountability determined.

The Risk Assessment Process

Risk assessment is a process engendered by the need to make risk management decisions in the face of uncertainty. Simulated scenarios and statistical analyses are used to try to determine the potential exposure to hazards, agents, and activities for various groups and to assess the potential outcomes of such exposure.

Most risk assessments generally follow a series of steps set out by the National Research Council. These steps include hazard identification and assessment, exposure assessment, risk characterization and risk assessment (Figure 1).

Figure 1. Steps in Risk Assessment

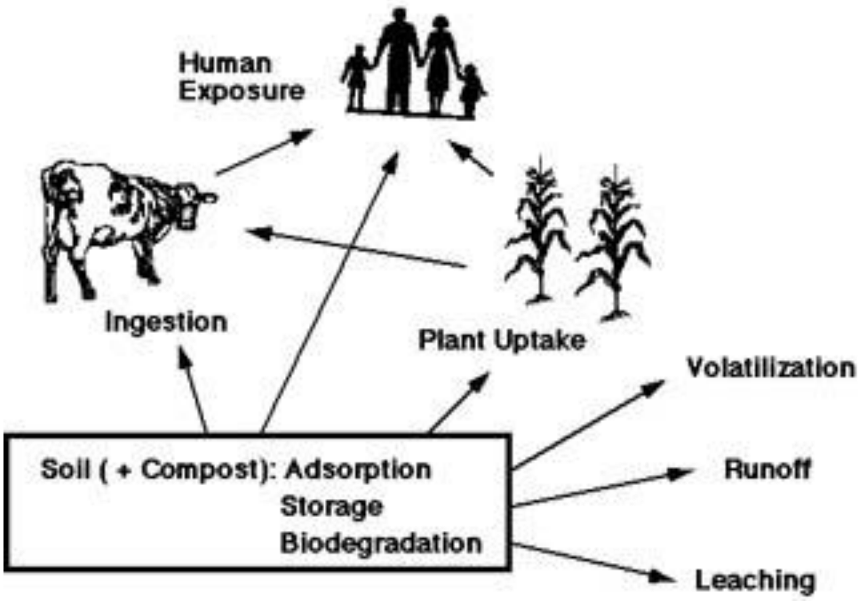
Hazard Identification: In MSW composting primary hazards for workers include pathogens and their toxins, organic chemicals (many of them are in common household items such as solvents and cleaners), and heavy metals (from items such as batteries and consumer electronics), as well as mechanical and related hazards. In the compost products concerns for consumers and the environment are principally the heavy metals and some persistent organics. Furthermore, potential hazards may come from three sources: those present in MSW, those materials transformed by composting, and those materials created by the composting organisms themselves (endotoxins, spores).

Hazard Assessment: Laboratory and ecological studies, as well as epidemiological studies of the distribution of disease and other adverse effects among people are needed to determine the potential outcomes of exposure to the hazards identified in composts and the composting process. The nature of effects on individuals, species, and living systems, as well as the time course over which these effects may take place, are needed to tie exposure to the outcome. Two points are particularly important in a risk assessment: the dose-response relationship (what exposure results in each level of effect) and the character of the effect itself. Chronic effects of low-level exposure (e.g., problems in reproduction, neurology, immunology, cancer) are much more difficult to assess than immediate and apparent harm.

Exposure Assessment: Exposure is the frequency, duration, and intensity with which an agent or activity is presented to a subject by various routes [inhalation, ingestion, or through the skin (dermal)]. Exposure can be direct, as for inhalation of MSW compost dusts and ingestion of compost/soil by children, or indirect by ingestion through the food chain (soil-> crop -> subject or soil -> water -> invertebrate -> fish -> subject). In instances where exposure is known or reasonably suspected to occur, such as with occupational exposure of workers, relatively simple models and assumptions can be used to simulate the nature of the exposure. Where exposure is suspected, but not well described and predictable, the common practice is to monitor potentially affected people and the media (air, water, soil, or food) with which they come in contact. Specific information about the behavior of the chemicals and the environmental conditions affecting their fate are used to refine our understanding of exposure. Background levels of contamination from other sources, including natural phenomena, must be identified and quantified. Monitoring of the MSW composting process, for example, has been useful in showing that potentially harmful levels of organisms associated with respiratory disease exist only in the immediate vicinity of a disturbed pile, even though such organisms are widely distributed throughout the environment.

Risk Characterization: Risk characterization sets the stage for risk assessment by developing both the models of exposure-response in test species and human beings and the means to convert one to the other. The exposure and hazard assessments are connected by an appropriate set of risk assessment scenarios - the likely pathways of exposure and conditions of concern. The exposure-response relationship calculated via these scenarios can yield an average or a range of values to be compared to accepted standards by the risk assessor (Figure 1). For MSW composts risk characterizations are most important for heavy metals and some persistent organics but have generally paralleled those of sludges.

Figure 2. Potential Fate of Contaminants in Compost



Risk Assessment Strategies

Once we have some knowledge of the distribution of exposures over time and some understanding of the outcomes from different types of hazards, the formal risk assessment of MSW composting and its products can be undertaken. Many assumptions must be made to construct appropriate mathematical models. Various strategies for risk assessment may differ substantially in their assumptions and approach, so different conclusions may be reached.

Most exposed individual (MEI) is a set of hypothetical scenarios employing "conservative" estimates and parameters intended to protect populations at risk by evaluating the outcomes of very high exposures in the laboratory and extrapolating to human populations exposed to very low levels of the pollutant. The MEI approach attempts to estimate the exposure of different parts of the population by assuming that the MEI is in the upper 95% for each factor considered in the estimate. Depending on the situation, the MEI may grossly over-represent a non-existent target or may ignore the extreme 1%. In any case, the MEI is sufficiently arbitrary and unrealistic as to create serious arguments. This approach is intended to represent special groups at disproportionate risk within the general population.

Alternative Pollutant Limits (APL) uses realistic exposure scenarios and pragmatic field data to identify the patterns of exposure likely to have unacceptable risk as well as those where risks are minimal. The exposure assessment assumes that compost is produced by the "best available technology" and applied to soils at reasonable rates as per "best management practice." If product testing at these levels fails to evoke adverse effects, then the highest level without effect is a "no-observable-adverse-effect-level" (NOAEL); presumably the material containing that, or a lower concentration can be used without restriction. The weakness in the APL approach is that it usually relies on empirical evaluation of component combinations and conditions which make prediction difficult for untested component combinations.

Uncertainty Analysis is an emerging approach that uses sophisticated simulation technology to consider the full range and shape of available data and to estimate the frequency with which critical risk values are likely to be exceeded. While it has not yet been applied to composts in a regulatory context, this approach is likely to offer the most advantageous insight into the existing data for heterogeneous materials and circumstances such as MSW composting.

Uncertainty pervades each step in the risk assessment process. Some of this uncertainty is due to the difficulty in making accurate measurements at very low concentrations or is systematic, i.e., due to uncertainty in the models, equations and understanding of the biotic systems involved. Other uncertainty results from physical and biological variation, i.e., random events such as weather, the frequency of genes in the target populations, etc. Taking all these sources and types of uncertainty into account in risk assessment offers several challenges for MSW compost. Research can narrow some of the uncertainty inherent in the risk assessment process, but risk assessors must provide clear, consistent estimates regarding the level of uncertainty for each step and for the overall process. To date that has not been the case for MSW composting and its products.

Risk Management and Related Policy Issues

Ultimately the purpose of *risk assessment* is to assist in *risk management,* that is, to help regulators, policy makers, and managers choose an appropriate course of action when necessary. The risk manager must balance many factors beyond the numbers generated in a risk assessment: the needs of communities who seek protection or to minimize their tax expenditures, the concerns of companies which will undertake remediation or want relief from what they see as oppressive regulations, and the interests of diverse agencies and jurisdictions with their own legislative mandates. Decisions must be made about which standards to apply, what groups to place at risk or protect, which remediation strategy can be employed, or what mitigation is immediately needed.

While the risk assessor's data, calculations, and reports may provide a foundation for such decisions, risk management also embodies values - political, social, economic, philosophical, and psychological - not present in the risk assessment process. Some of these related policy issues are outlined below.

Determination of "acceptable risk": No amount of scientific research can draw a clear line between "safe" and "unsafe." There may be a threshold below which *no* effects are seen, but usually risk managers must decide "how much risk can we tolerate?" Not only must they ask, "how clean is 'clean'?"; they must also decide "how dirty can we get away with?" Determinations of "acceptable risk" may differ for different populations. For the general population, ranges from 1/10,000 or 1/million additional deaths are commonly takenas acceptable levels of risk. Because workers are presumably compensated for some of the risks they face, their level of "acceptable risk" is generally ten-to a hundred-fold higher. *De minimis* risks are those which are too low or infrequent for society's attention; *de manifestus* risks are those for which action is obligated by law, common decency, or economic liability. "Acceptable risk" is at least bounded by these factors.

Incremental vs. total risk: Differences in the point of view of "risk" by diverse statutes, agencies, and scientific disciplines have largely resulted in a focus on "incremental risk" with respect to a particular activity. That is, how much more risk does this activity add (or remove) compared to the risk already present? However, the potential widespread, unrestricted use of MSW composts (in contrast to the somewhat more limited production of a soil amendment which may be restricted to certain uses such as reclaiming a contaminated site) raises the more complex issue of whether "total health risk" must be considered. Even a small increment of lead, for example, may be detrimental to children in some localities, but in others the heavy metal binding capacity of the compost may reduce bioavailability of lead-contaminated urban soils. Assessments need to realistically consider the sum of all exposure pathways and of equivalent consequences and to justify the approach, whether incremental or total.

Multi-component interactions: MSW is undoubtedly the most complex case of multiple chemical exposure because there are so many diverse components in the waste stream. Researchers have already documented interactions between some of the organic chemicals detected in MSW compost, but not at those low concentrations. Most risk assessments, however, consider only one potential hazard at a time by either ignoring interactions or summing similar effects. Higher order functions, such as cognitive development, reproduction, and immune response, are just being widely tested for single and multiple component effects.

Projected product use: Different standards may be appropriate depending on the use of the composts. An already compromised environment, such as the cap on a

Superfund site or strip mine, should be assessed differently than unrestricted use as a soil amendment.

Obtaining missing information: There are serious gaps in data available regarding the bioavailability as well as the environmental and health effects of trace metals and organic compounds in compost. In addition, little is known about the environmental impact on amended soils regarding soil formation, nutrient cycling, succession, communities of microorganisms and invertebrates, and biodiversity. Limited studies of variability and other uncertainties regarding composition and toxicity need confirmation. Obtaining reliable data from a cohesive set of evaluative studies designed to answer questions of risk must be a priority.

Hazard Identification and Assessment

Depending on the operations, design, and the quality control program, MSW composting workers may be exposed to a number of pathogens, toxic substances, and other physical and chemical hazards (see box). In addition, the composting process uses equipment and machinery that can have their own notable hazards which are not specifically addressed here. Note that a variety of safety practices and equipment have been introduced and adapted to the several parts of the MSW composting process, so that some or all the risks may be appropriately managed.

Acute Health Concerns

While a variety of primary pathogens are present in MSW, the composting process kills most of them, and exposure-related infectious disease from primary pathogens among compost workers has not been documented. "Secondary pathogens" - fungi and other micro-organisms produced during the composting process on the other hand, are of greater concern. A variety of symptoms, ranging from red and irritated eyes to runny nose and nausea, have been reported and may be attributed to dust-borne bacterial and fungal spores and endotoxins from organisms present in MSW or growing in the compost.

The most serious health threat seems to come from a secondary pathogen, the heat tolerant fungus *Aspergillus fumigatus,* and several related fungi which cause "aspergillosis" (also known as "farmer's lung" or "brown lung" disease). This fungus, a well-known product of silage, manure compost, and wastewater sludge compost, grows well on decaying vegetable matter at temperatures above 45°C, and thus survives most of the composting process. Infection of susceptible individuals (including those on immunosuppressant drugs, antibiotics, on adrenal corticosteroids, or with pulmonary disease, asthma, and certain other infections) may be severely debilitating and even fatal. Such infection appears related to high levels of "infective units" in dusts, perhaps reflecting interaction with other materials as irritants, because the organism itself is ubiquitous and not regarded as an off-site or product-related problem.

The corrosive and flammable nature of unprocessed MSW also clearly poses a risk to workers. "Sharps" (broken glass, metal edges, etc.) require physical protection (gloves, goggles, face masks, guards, etc.). Explosive materials may also present a hazard. These problems need management, training, and equipment design, mostly provided free of charge.

Finally, allergens and endotoxins released by the breakdown of microbes or the vegetable matter on which they are growing can evoke local inflammation and congestion. A full-blown, serious response may occur in sensitive individuals, but such sensitization appears to be overcome by repeated exposure, since sludge and compost workers develop resistance over time.

Chronic Health Concerns

Relatively little is known about the long-term exposure of workers to low levels of persistent organic chemicals - PCBs, PAHs, dioxins, pesticides, and numerous other chemicals - common in MSW because of household use or by-product formation in commerce and industry, etc. Many of these chemicals are known or suspected carcinogens; some (dioxins) are among the most toxic chemicals known. The fraction of these are available, even when inhaled or ingested, appears very small. Concerns about such chemicals arise because so relatively few have been sufficiently evaluated to assess the dangers of long-term, low-level exposure, particularly regarding immune system suppression or activation and reproductive or nervous system effects, for example.

In addition, health and safety concerns are often assessed regarding the toxicity of *individual* chemicals present in MSW. Little is known about levels of safety for exposure to the *total* load. The total concentration of volatile organic chemicals, for example, may reach unacceptable chronic levels in poorly ventilated acceptance/sorting areas. Even small amounts of solvents, paints, cleaners, and related materials in MSW can, in total, present substantial exposure, so it is essential to consider the total load as sets of equivalents with respect to selected endpoints.

Exposure Assessment

Almost all worker exposure to infective or toxic materials originates as dusts, aerosols, and vapors, which are either inhaled or ingested. Some chemicals in the MSW and compost may present exposure via the skin, either directly or because of dust dispersion. Exposure to these materials may occur at any one of three stages in the composting process: initial introduction and sorting, early handling of moist composting materials, and handling of relatively dry finished compost.

The exposure of workers using MSW compost in agriculture, horticulture, and landscape remediation (e.g., strip mine reclamation or Superfund site capping) will differ from that of the worker on the sorting floor. Understanding "exposure pathways" (that is, the means and forms by which a chemical or pathogen moves from its source to a target) can help to identify options to monitor and reduce risks to workers.

Assessing the extent of worker exposure to toxins, however, is complex. The mere presence of toxic chemicals, pathogens, and allergens in MSW or MSW compost does not in and of itself create a risky situation. Rather, exposure ("duration" times "concentration" or "frequency") to pathogens or chemicals must be related to the number of organisms or amount, respectively, entering the body. That amount must be related to an adverse effect, which may (e.g., nervous system disorders, birth defects) or may not (e.g., cancer, mutations) have a threshold below which no effects are seen. Although we presently lack inexpensive technologies for measuring exposures for individual chemicals and for testing for thresholds of toxic agents, the time should not be far off when combinations of biotechnology and computer science permit personal monitors and similar devices. These would assist in removing perceived obstacles to stating that an activity is "safe." Sampling pathogens within material as diverse as MSW is exceedingly difficult, but composts are more homogeneous and enable assurances of a "pathogen-free" products.

Risk Characterization

The great variety of the incoming MSW waste stream, the equipment used in sorting, and operational variables makes a generic classification of risk practically impossible without acceleration of research on areas of process standardization, quality control and quality assurance, exposure assessment (especially bioavailability of metals and persistent trace organics), and hazard assessment (especially multiple chemical interactions). To date, health and safety concerns have played less a role in siting and operation than noxious odors, traffic, and noise. Unrestricted land application of compost sand sludges is seen variously as a waste management approach, a recycling resource, and a potential threat to environmental health and safety. Advocacy of these several views in the face of uncertainties and data deficiencies adds its own stress.

Hence, better studies are needed to help define the certainty of occupational risks. Historical experience with silage, composts from manure and sludges, and related agricultural activities categorizes MSW composting as a familiar, albeit sometimes troublesome process. Attention to hazard mitigation for workers by equipment, training and alert management remains important. As occupational health and safety in manufacturing industries has become increasingly sophisticated as a management field, many previously "dangerous" occupations now have exemplary safety records. Both management and workers believe they can create a more effective and efficient working environment in which worker concerns are answered successfully while internal and external liability costs are contained.

WORKER HEALTH & SAFETY: ASSESSING OCCUPATIONAL RISKS

While many concerns have been raised about the potential harm from MSW management to the environment, public, and wildlife, the risks and consequent costs of occupational hazards in waste management activities have received relatively little attention in the rush to adopt or adapt technologies such as composting. The attitudes of many concerned with various hazards of MSW management appear to be rather blasé regarding worker health and safety.

This lack of attention appears to stem from the presumption that, however MSW is handled, workers will either be protected by standing occupational health and safety (OHS) rules, recently adopted industry practices, and operating guidelines, or that liabilities will be reduced by appropriate management by the responsible contractor/agency. Further, the minimal skill/education level for MSW compost workers as compared to other manufacturing and production areas, the general absence of workers' and professional operators' organizations, the tardiness of state and federal agencies in creating certification and training standards for operators, and the public's inclination to ignore the full costs of waste management also contribute to this issue. Any unsettled issues regarding worker health and safety deserve serious evaluation as political or regulatory decisions about MSW composting are made.

Immediate and wide-spread threats from exposure to MSW and MSW compost are not apparent, but more needs to be known about long-term exposure to be able to adequately define the risk to workers. There are clearly components (organic chemicals, heavy metals, and microbial/fungal toxins) in MSW and immature compost which may cause harm from exposures at or near levels commonly found during sorting and compost production. In general, occupational risks are evaluated within a more narrow context than those for the general population and specifically assume an adult-only exposure period of 40 hours/week, 50 weeks/year for a 30-year working lifetime.

Potential Hazards for MSW Workers:

- Primary human pathogens, including viruses, mycoplasmas, bacteria, fungi, and cysts or eggs of intestinal parasite, found primarily in disposable diapers and tissues and household medical wastes
- Secondary pathogens and their toxins, e.g., spores and endotoxins generated by bacterial and fungal growth within the composting process itself
- Volatile and semi-volatile organic chemicals of both synthetic and natural origin (including noxious odors)
- Persistent, lipophilic organic chemicals
- Metals, other inorganic materials (e.g., asbestos), and organometallics
- Allergens from household and yard wastes
- Corrosive, caustic, explosive, and sharp materials

References

See the fully referenced article in a special issue of *Biomass & Bioenergy* (Vol. 3, Nos 3-4, pp. 163-180, 1992), from which this fact sheet is extracted. A copy of that journal containing 11 articles on MSW composting can be obtained through the Composting Council, 114 S. Pitt St., Alexandria, VA 22314, for $30.

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Cornell Waste Management Institute ©1996
Dept of Soil and Crop Sciences
Bradfield Hall, Cornell University
Ithaca, NY 14853-5601
cwmi@cornell.edu