HAZARDOUS WASTE

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Contents

Summary

Hazardous waste definitions differ from one country to another. A generic definition might center on wastes or combinations of wastes that pose a substantial present or potential hazard to humans or the environment, in part because they are not readily degradable, persistent in the environment and are deleterious to human health or natural resources. Most hazardous wastes are produced in the manufacturing of products for domestic consumption or further industrial application.

Nuclear wastes are a major and controversial hazardous waste that are created during a variety of human activities in numerous sectors, including academia, federal agencies, industry, mining, medical facilities and utilities. At the Nonproliferation Treaty Conference in May 2000, the five nuclear weapon states, China, France, the USA, Russia, and the United Kingdom, agreed to disarm their nuclear arsenals, but no timeline for achieving this goal was set. In addition, the current OSPAR Convention (Convention for the Protection of the Marine Environment of the North-East Atlantic) Strategy commits to achieving negligible radioactive discharges, emissions and losses to the maritime environment by the year 2020. In light of the nuclear incidents at Three Mile Island and Chernobyl, much was learned about the risks of using nuclear energy, as well as the uncertainties in public risk perception and behavior when people are faced with nuclear emergencies.

Hazardous wastes can damage the environment and natural resources, and they can cause *inter alia* cancer, infections, irritations (mainly due to allergic response), or mutations. In addition to proper hazardous waste disposal or, if necessary, remediation of contaminated sites, it is important to minimize the production and impact of hazardous wastes and to recover and recycle resources where feasible. Industrial Ecology is a framework for minimizing energy and materials usage by designing and operating anthropogenic systems that are interdependent and sustainable with natural systems.

In order to properly manage hazardous waste and allocate public resources, risk assessment and management has evolved as important decision-making framework. Ultimately, national hazardous waste management programs should strive for strong regulatory regimes coupled with efficacious market instruments to promote sound industrial hazardous waste management practices. Further, incentives should be created to use and innovate advanced hazardous waste and waste reduction technologies insuring global equity. International solutions to hazardous waste issues must also be pursued to help less developed countries (LDCs) with their hazardous waste management programs and to prevent illegal hazardous waste dumping and trading as increasingly stringent regulations in developed countries continue to make hazardous

waste disposal more expensive.

1. Definition of Hazardous Wastes

One of the challenges facing proper hazardous waste management and disposal is that definitions of hazardous wastes vary from one country to another. The term hazardous waste is in itself ambiguous. Effective governmental programs must provide appropriate, scientifically defensible, and clear legal definitions for wastes being regulated. However, this can be difficult. In the U.S., for example, the Environmental Protection Agency took nearly four years after the passage of the first U.S. hazardous waste law in 1976 to promulgate regulations that defined hazardous waste. This definition, however, used broad terms, included many exceptions and has needed modification from time to time. Other nations have had similar experiences. Definitions often do not have a solid scientific foundation and may allow exemptions as a result of political influence.

A general definition describes hazardous wastes as wastes or combinations of wastes that pose a substantial present or potential hazard to humans or other living organisms or natural resources because they are nondegradable or persistent in nature, can be biologically magnified, can be toxic, or may otherwise cause detrimental cumulative effects. Hazardous wastes contain organic or inorganic elements that, due to their toxicological, physical, chemical, carcinogenic or persistency properties, may cause:

- Explosion or fire;
- Infection, including infection by parasites or their vectors;
- Chemical instability, reactions or corrosion;
- Acute or chronic toxic effects;
- Cancer, mutations or birth defects; or
- Damage to ecosystems or natural resources.

In addition to these properties, the location or utility of a substance may also determine whether it is a hazardous waste. A pesticide used to treat crops for instance, may be considered hazardous waste after if it has migrated to surface or groundwater. On the other hand, if an industry finds a use for a particular hazardous waste in its manufacturing process, the substance may become a valuable economic input.

2. Sources of Hazardous Waste

The term hazardous waste often includes by-products of industrial, domestic, commercial, and health care activities. Rapid development and improvement of various industrial technologies, products and practices may increase hazardous waste generation.

Most hazardous wastes are produced in the manufacturing of products for consumption or further industrial application. Hazardous waste sources include industry, institutional establishments, research laboratories, mining sites, mineral processing sites, agricultural facilities and the natural environment. All sources that discharge liquid, gaseous or solid wastes that fit the above definition can be regarded as sources of hazardous wastes.

Some major sources are agricultural land and agroindusty, households, mines and mineral processing sites, health care facilities, commercial facilities, institutional facilities, industrial sites, solid waste disposal sites, contaminated sites and building materials. Major hazardous waste sources and their pollution routes in the environment are listed below.

Agricultural land and agro-industry: Hazardous wastes from agricultural land and agro-industry can expose people to pesticides, fertilizers and hazardous veterinary product wastes. Farms are a major source of these wastes, and agrochemicals can leach into the environment while in storage or can cause damage after their application.

Domestic: Households stock various hazardous substances such as batteries and dry cells, furniture polishes, wood preservatives, stain removers, paint thinners, rat poisons, herbicides and pesticides, mosquito repellents, paints, disinfectants, and fuels (i.e. kerosene) and other automotive products. These can present a variety of dangers during storage, use and disposal.

Mines and mineral processing sites: Mining and mineral processing sites handle hazardous products that are present in the additives, the products and the wastes.

Health care facilities: Health care facilities are sources of pathological waste, human blood and contaminated needles. Specific sources of these wastes include dentists, morticians, veterinary clinics, home health care, blood banks, hospitals, clinics and medical laboratories.

Commercial wastes: Commercial waste sources include gasoline stations, dry cleaners and automobile repair shops (workshops). The types of hazardous wastes generated by these sources depend on the services provided.

Institutional hazardous waste sources: Institutional hazardous waste sources are mainly research laboratories, research centers and military installations. Some military installations are used for the manufacture and storage of ammunition, and they are also used as testing grounds for military hardware. Military establishments also carry out activities that generate other types of hazardous wastes of household, commercial and industrial nature.

Industrial hazardous waste sources: Hazardous wastes are created by many industrial activities. For example, the hazardous wastes from the petroleum fuel industry include the refinery products (fuels and tar), impurities like phenol and cyanides in the waste stream, and sludge flushed from the storage tanks.

Solid waste disposal sites: These are mainly disposal sites for municipal solid waste, but hazardous wastes that have not been properly separated from other wastes are also at these sites. In developing countries, solid waste disposal sites are a major source of pollutant-laden leachate to surrounding areas, as well as recyclable materials for scavengers, who can collect and resell waste materials that have been exposed to or that contain hazardous substances.

Contaminated sites: These are sites that are contaminated with hazardous wastes due to activities that use or produce hazardous substances or due to accidental spills. Former sites of industries that used or produced hazardous materials belong to this group.

Building materials: Roofs and pipes made of materials incorporating asbestos, copper, or other materials may present a source of hazardous waste.

3. Classification of Hazardous Waste

Waste characterization is a critical step in determining how a waste should be handled in bulk or in packaged form. Common hazardous wastes include waste oil and fuel; solvents and thinners; acids and bases/alkalines; toxic or flammable paint wastes; chlorinated solvents, heavy metals, perchlorates and peroxides; abandoned or used pesticides; and some wastewater treatment sludge. Special hazardous wastes in the U.S. include industrial wastes containing Environmental Protection Agency (USEPA) priority pollutants; infectious medical wastes; explosive military wastes; and radioactive wastes or releases.

By way of examples, the U.S. has identified two general waste categories as hazardous. Wastes may be specifically identified or listed in the Federal and/or the State regulations, or they may be defined by physical or chemical characteristics. Specifically, under the U.S. Resource Conservation and Recovery Act (RCRA), a waste may be a designated hazardous waste or a characteristic hazardous waste.

A **designated waste** (or listed hazardous waste) in the U.S. is one that is specifically listed by the USEPA as hazardous. A **characteristic waste** is one that exhibits any one of the characteristics of ignitability, corrosiveness, reactivity, or toxicity. The U.S. Federal government level defines an **ignitable waste** as any liquid with a flash point of less than 60 degrees C (140 degrees F), any non-liquid that can cause a fire under certain conditions, or any waste classified by the U.S. Department of Transportation (USDOT) as a compressed ignitable gas or oxydizer. A **corrosive waste** is defined as any aqueous material that has a pH less than or equal to 2, a pH greater than or equal to 12.5, or any material that corrodes steel (SAE 1020) at a rate greater than 0.25 in/year (1 in. = 2.54 cm). A **reactive waste** is defined as one that is unstable, changes form violently, is explosive, reacts violently with water, forms an explosive mixture with water, or generates toxic gases in dangerous concentrations. A **toxic waste** is one whose extract contains concentrations of certain constituents in excess of those stipulated by the U.S. Safe Drinking Water Act (SDWA). The hazardous waste identification regulations that define the characteristics of toxicity, ignitability, corrosivity and reactivity, as well as the tests for these characteristics, can vary.

4. Public Health and Environmental Effects of Hazardous Wastes

Hazardous wastes can damage the environment by contaminating air, water and soil. Once in the environment, hazardous wastes can affect all life forms. Whether through direct exposure or environmental damage, hazardous wastes present a risk to human health.

In the 1950s and 1960s in the U.S., there was a dramatic decline in the populations of several predatory birds due to dioxin exposure. DDT exposure at low levels was found to interfere with calcium deposition in the eggshells of birds of prey, causing them to be thin and fragile and often to be crushed by the parents in the nest. One well-known species affected in this way was the Bald Eagle (Plate 1).

Plate 1. The Bald Eagle

Toxic effluents such as those from improperly managed mining operations can have very serious effects on wildlife and pose serious threats to human health (Plate 2). Marine ecosystems and wildlife have also suffered major damage as a result of oilspills resulting from accidents to large ocean-going tankers (Plate 3).

Safety related properties of hazardous wastes include their tendency to corrode, explode, burn or cause chemical reactions. Safety effects resulting from hazardous wastes include injury and even death from an explosion, fire outbreak, chemical reaction or other hazardous situation created by such wastes.

Effects to property and the physical environment mainly pertain to property damage, which can also result from fires and explosions. These incidents, which result from improper hazardous waste management, may emit hazardous substances to the atmosphere as well, causing deleterious health effects, through inhalation for example.

Plate 2. Acid mine drainage.

Plate 3. National Oceanic and Atmosphere Administration (NOAA) Workers remove wildlife from contaminated area after Exxon Valdez oil spill in Prince William Sound, Alaska.

Health related properties of hazardous wastes include their tendency to cause cancer, infections, irritations (mainly due to allergic response), mutations or other toxic or radioactive effects. Health effects from hazardous waste exposure occur after hazardous components enter the body through inhalation, skin absorption, ingestion, or puncture wound. The health effects of the hazardous wastes are dependent on the amount (doses), and routes and duration of exposure. Temporary health effects of hazardous waste exposure can include dizziness, headaches and nausea, while prolonged exposure can also result in cancers, disabilities or death.

Hazardous wastes from some household waste sources are prone to easily cause health hazards due to their proximity to potential receptors. Wastes from other sources are further from given receptors so their exposure routes are longer. This may result in masking or delayed manifestation of exposure effects.

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Bibliography

Cortinas de Nava, Cristina. Worldwide Overview of Hazardous Wastes. Hazardous Wastes and Public Approaches. Hazardous Waste Conference, 1993. [Discusses international and transboundary hazardous waste issues]

Grasso, D. (1993) *Hazardous Waste Site Remediation: Source Control*, CRC/Lewis Publishers, Boca Raton, Florida. [Discusses major topics of environmental hazardous waste management focusing on source control and site remediation].

Kiely, G. (1997). *Environmental Engineering*. McGraw – Hill. New York. [Discusses major topics of environmental engineering, including hazardous waste management].

LaGrega, Michael D; Buckingham, Phillip L.; Evans, Jeffrey C. (1994). *Hazardous Waste Management, 1146 PP*. New York, USA: McGraw-Hill, Inc.

Marwa, C. (2000). Management of Solid Waste from the Dry Cell Factory - Case Study Matsushita Electric Company (EA) Ltd. Unpublished report, Department of Environmental Engineering, UCLAS. [Inventory of solid waste management at a dry cell manufacturing facility with a focus on hazardous components].

Mbuligwe, S. E. (2002). The Health and Environmental Trail of Agrochemicals Use in Tanzania: Root Causes, Impacts and Mitigation Prospects. In Press: The Journal of Building and Land Development. [Review of background to and implications of agrochemicals use in Tanzania].

Mtalo, J. O. and Swai, CL (1996). Investigation of Health Care Solid Waste Management in City Health Facilities. Urban Health Project (Unpublished Report). [An inventory of health care waste management situation in Darres Salaam City].

O'Neil, Kate. Out of the backyard: the problems of hazardous waste management at a global level. *Journal of Environment & Development*. 7 (1998): 138 [A review of worldwide hazardous waste management problems and hazardous waste trading].
Probst, Katherine, N; Hazardous Waste Management. (developing countries). *Environment*, November 1999. Copyright 1999 Heldref Publications. [An overview of hazardous waste management issues in developing countries].

Biographical Sketches

Domenico Grasso, Picker Engineering Program, Smith College, Northampton, MA 01063

Professor Domenico Grasso is the Rosemary Bradford Hewlett Professor and Founding Chair of the Picker Engineering Program a Smith College and holds adjunct faculty appointments at the Universities of Connecticut and Massachusetts and Yale University. An environmental engineer who studies the ultimate fate of contaminants in the environment and develops new techniques to reduce the risks associated with these contaminants to human health or natural resources, he focuses on molecular scale processes that underlie nature and behavior of contaminants in environmental systems.

He holds a B.Sc. from Worcester Polytechnic Institute, an M.S. from Purdue University and a Ph.D. from The University of Michigan. He is a registered Professional Engineer in the states of Connecticut and Texas, and was Professor and Head of Department in Civil & Environmental Engineering at the University of Connecticut prior to joining Smith. He has been a Visiting Scholar at UC-Berkeley, a NATO Fellow, and an Invited Technical Expert to the United Nations Industrial Development Organization in Vienna Austria. He is currently Chair of the Environmental Engineering Committee of United States Environmental Protection Agency Science Advisory Board, President of the Association of Environmental Engineering & Science Professors, and Editor-in-Chief of *Environmental Engineering Science*. He has authored more than 100 technical papers & reports, including four chapters and two books. Federal, state and industrial organizations have supported his research work.

In 1998, Professor Grasso served on a World Bank funded international team of scholars that established the first environmental engineering program in Argentina. In 2000, *The Water Environment Federation* named him a Pioneer in Disinfection. He recently chaired a U.S. Congressional briefing entitled Genomes & Nanotechnology: The Future of Environmental Research.

Professor Grasso views engineering as a bridge between science and humanity and making it particularly well suited for incorporation into a liberal arts environment. His classes, although technically rigorous, also explore the societal and philosophical issues facing engineers and scientists.

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Danielle J. Kahn is currently an AmeriCorps service member working with the Center for Ecological Technology (CET), whose headquarters are in Pittsfield, Massachusetts, U.S.A.. There she is working with CETs Office Paper Recycling Services, the Recycled Products Purchasing Cooperative, and the Massachusetts Materials Exchange. Danielle also recently returned from Ecuador, where she was working for Fundacion Jatun Sacha at its Ilalo Urban Forestry Reserve. A recent graduate of Smith College, she received her degree in Environmental Policy, a self-written major combining economics and public policy to study environmental issues. During her time at Smith, Danielle served as a research assistant for Dr. Fletcher Blanchard and Dr. Domenico Grasso. Her current interests include industrial ecology and environmental chemistry and biology. She hopes to have a chance to pursue these interests in graduate school within an interdisciplinary framework that combines the study of both science and policy to address environmental issues.

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