Management of Hazardous Wastes

Managing hazardous wastes is a growing concern in many countries. The long-term impacts and costs of improper disposal can be very high, and the emphasis must be on prevention. A comprehensive management system should include (a) policies, institutions, and effective regulations and (b) adequate and acceptable disposal facilities, either public or private. This chapter outlines the key elements of such a system.

Improper disposal of hazardous wastes is an increasing problem in many developing countries. Typically, but not ideally, the first stages of pollution control focus on discharges into air and water, leaving a wide range of other materials that are poorly controlled. These materials include substances that pose serious threats to public health and the environment and that are considered hazardous under almost any definition. Examples include sludges from chemical plants, clinical wastes, contaminated oils, and metal-bearing wastes. Materials of particular concern are those that do not degrade quickly in the environment, such as metals and persistent chemicals, and that can pose a threat for long periods into the future.

Proper management and disposal of hazardous wastes is expensive, and therefore illegal dumping is common in many areas. The consequences include not only environmental degradation but also the undermining of legitimate waste management systems. Control of dumping is thus a key issue to be considered when designing and implementing regulations.

The World Bank can assist governments in designing and implementing hazardous waste management systems and in the provision of appropriate treatment and disposal facilities, often with the involvement of the private sector.

Scale of the Problem

Definitions

Hazardous waste can be defined in a number of ways including:

- Hazardous characteristics (e.g., toxicity and flammability)
- Certain toxic components (e.g., PCBs and arsenic)
- Types of materials (e.g., organic solvents and explosives)
- Processes from which hazardous wastes originate, such as refining and clinical work
- Specific waste streams such as chemical wastewater treatment sludges.

Defining hazardous waste is difficult, but the establishment of a proper management framework in developing countries should not be delayed by debates about what constitutes a hazardous waste. Pragmatic working definitions can be adopted initially and refined as the system is developed.

Many countries adopt an inclusive approach that specifies which wastes are to be considered hazardous for regulatory purposes. Clearly, there have to be procedures for granting exceptions and for adding and deleting wastes.

Estimates

Although for planning purposes it is necessary to estimate the total volume of waste produced, one should avoid putting too much effort into trying to refine numbers. Estimates are inherently unreliable, for several reasons. To begin with, recorded data on waste quantities are almost never available, and quantities have to be estimated on some basis such as number of firms, value of output, or number of employees. The coefficients for such estimates are very unreliable,

and the resulting figures can vary by an order of magnitude. Even where estimated quantities are available, definitional questions can have a major impact. For example, wastes from mining or materials processing can often be a major portion of the total, and their reclassification can have a significant effect on the estimates of total "hazardous" wastes.

A related planning problem is the highly elastic nature of waste generation. Once real disposal costs are imposed on the generators through regulatory effort the reductions in waste quantities can be dramatic. Experience has shown that wastes delivered to treatment facilities have, in some cases, been only one third of the design estimates of wastes generated. This drop is ascribed to a combination of waste reduction and evasion of the regulatory system.

For practical purposes, estimates of quantities should be based on a relatively narrow definition, perhaps in terms of specific industries or process streams, and realistic allowance should be made for the effects of waste minimization.

Policy and Regulation

Hazardous wastes are by their nature a threat to public health and the environment and therefore need to be regulated under the full force of the law. However, management of hazardous wastes is complex, and regulations must be developed within the context of a comprehensive policy that covers the responsibilities of different parties, methods for defining hazardous wastes, incentives to reduce quantities, education of waste generators and the public, the establishment of approved facilities (with particular concern for criteria for siting), and systems for controlling and monitoring the movement and disposal of hazardous wastes. Legislation on hazardous wastes should be coordinated with other related topics such as management of hazardous materials and industrial health and safety.

The establishment of a hazardous waste management system is often complicated by a "chicken and egg" problem: legislation may require disposal in approved facilities, but such facilities are expensive and will usually not be established until legislation and enforcement have demonstrated the scale of the "market" for proper disposal. In the initial stages, therefore, industry may be in the position of having no realistic options for compliance with the law. Government policy must therefore address the problems of phasing in the new regulations, by assisting in the provision of some acceptable facilities or by licensing interim solutions.

Basel Convention

There have been a number of cases of export of hazardous wastes from countries with strict regulations to those without similar controls, resulting in serious pollution problems in the receiving countries. This trade in hazardous wastes is now controlled under the Basel Convention (the Global Convention on the Control of Transboundary Movement of Hazardous Wastes, adopted at Basel in 1989). The convention also promotes the development of sound national management of hazardous wastes as a prerequisite for the control of transboundary movement.

Components of a Management System

Prevention

Ideally, the generation of hazardous wastes should be avoided altogether. It is clear from experience in industrial countries with strong controls on hazardous wastes that it is possible to eliminate certain wastes and make major reductions in others. This is achieved by imposing the real costs of disposal on the generators, at which point the incentives for cleaner production and waste minimization become very strong. Where the production of the hazardous waste cannot be eliminated, action should be taken to reduce the hazardous characteristics by treatment or immobilization.

Responsibility for Wastes

Unfortunately, proper treatment and disposal is costly, while illegal dumping is very cheap and therefore profitable for illegal waste haulers. An effective control system is essential both to protect the environment from illegal dumping and to internalize the disposal costs to waste generators in an equitable way. The basic principle underlying control systems is that waste generators

should be responsible for the final disposal of their wastes in an acceptable manner.

In practical terms, three different actors have to be considered in waste management: the generator, the disposal facility, and the transporter of the wastes between the first two. The law will normally put the responsibility on the generator, but there must be a system that allows the government to monitor the movement of wastes from the generator to approved disposal. Such a system normally consists of a number of elements. These include placing formal responsibility on the generator to prove its compliance with disposal requirements, licensing waste haulers and disposal facilities, and establishing a manifest system to track the movement of wastes.

In the design of a manifest system, care must be taken to provide sufficient control without generating excessive administrative or regulatory effort. The basic principle is that each load of waste is accompanied by a multicopy document that identifies the characteristics of the waste, the approved disposal facility, and the responsible companies or individuals. Copies of the manifest are held, at a minimum, by the generator and the disposal facility. The manifest can provide valuable information to the authorities about patterns and trends in waste generation and disposal and make possible confirmation of compliance with regulations.

Storage of Hazardous Wastes

A hazardous waste management system should include regulations governing the storage of hazardous wastes at the generator's site or at any other transfer or disposal facility. In the absence of approved (or affordable) disposal options, it is common for generators or transporters to store wastes as a stopgap measure, but this approach can result in neglected piles of deteriorating wastes that pose significant hazards. It is not acceptable to allow generators to stockpile wastes over an extended period of time as a way of avoiding disposal problems.

Treatment and Disposal Facilities

Hazardous waste facilities frequently comprise storage, recovery, and treatment stages, as well as final disposal. This allows the facility to take advantage of economies of scale and of opportunities to blend different waste streams and to recover some materials, particularly oils and solvents. Such a facility can be complex and needs proper management and supervision. Potential operators need to demonstrate the necessary technical, financial, and managerial capabilities before a license to operate is issued. Any discharges from the site to air or water need to be very closely controlled and monitored.

Final disposal is almost always incineration or landfill. (Since incineration generates an ash, which is normally landfilled, it is sometimes considered a treatment step rather than final disposal, but this distinction is not often important.)

Incineration

Incineration involves the thermal destruction of gaseous, liquid, or solid wastes. Thermal oxidation converts complex organics into simple compounds, greatly reduces waste volumes, and can recover the heat content of wastes. Incineration requires relatively high temperatures (typically above 1,000°C), normally requires control of flue gases, and generates small quantities of ash or slag.

Hazardous waste incineration normally takes place in purpose-built facilities whose high capital and operating costs require significant throughputs for economic viability—typically, more than 10,000 metric tons a year. This required scale limits their feasibility in many newly industrializing countries.

Incineration is an accepted form of disposal for certain wastes in industrial countries, where careful gas cleaning and monitoring are required. Similar systems can be suitable for developing countries if adequate attention is given to the management and monitoring aspects.

Successful incineration requires good design and careful operation. The key operational characteristics are temperature, residence time, and turbulence in the combustion chamber, all of which affect the efficiency of destruction. A poor installation can emit particulates, acidic gases, unburned wastes, and trace quantities of hazardous organic by-products. Some wastes,

such as PCBs, require careful control to ensure, for example, that minimum temperatures are maintained.

Selected wastes can be incinerated in high-temperature process plants such as cement kilns. However, the waste stream must be limited to those wastes for which full destruction can be ensured and no unacceptable residues are emitted.

Landfills

The final disposal for many hazardous wastes or their treated residues is controlled land disposal. However, a properly located, engineered, and operated hazardous waste landfill is a major facility, not to be confused with the uncontrolled or open dumping that frequently occurs. Such controlled or "secure" landfilling should be used only for the minimal quantities of remaining wastes after all possible reduction and treatment have been carried out.

The main environmental threat of a landfill is water pollution. A landfill should be sited where the geological and hydrological characteristics are least likely to allow impacts on groundwater or surface water.

A well-designed, secure landfill is normally divided into a number of cells to allow for better control of operations and to allow segregation of incompatible wastes. The landfill is lined, often with a double or even triple lining, and has leachate collection facilities and groundwater monitoring systems. The design should include provisions for the closure and long-term monitoring of the site. Operation of the landfill should include requirements for pretreatment and containment of wastes, control and recording of the burial of different waste types, planning and preparation for spills and accidents, and regular monitoring of the surrounding environment.

The joint disposal of domestic and certain selected industrial wastes in a properly designed and operated municipal landfill may be acceptable as an interim measure or where investigations have demonstrated that the wastes involved are compatible. (For example, waste motor oils or some sludges may be acceptable.) However, such joint disposal should be carefully controlled with regard to the type and quantities of industrial wastes and should not be used as a cheap alternative to proper management of these wastes.

Development of a Hazardous Waste Management Plan

The key steps in a systematic approach to developing a national hazardous waste management plan can be summarized as follows. (For further details, see Batstone, Smith, and Wilson 1989.)

- Define the scope.
- Define the objectives and constraints.
- Formulate the key questions to be addressed.
- Collect the necessary information.
- Prepare a technical assessment of appropriate available technologies.
- Review the existing situation and develop a short list of critical problems and the technical options.
- Prepare a number of alternative management plans, based on the preferred technical options.
- Conduct review, discussion, and feedback.
- Make decisions and carry out implementation and regular monitoring and adjustment.

Economic Justification of Hazardous Waste Management Programs

Given the amount of public attention focused on hazardous wastes, it is surprising how little is known about the nature and scope of the risks involved. While the *potential* risks to public health from exposure may be significant, not much is known about the *actual* risks to public health. There is a significant lack of epidemiologic dose-response data linking the level of exposure to various toxins in the ambient environment with human health impacts. The lack of solid data on risks will continue to limit our understanding of the benefits of hazardous waste regulation. Very few studies or formal risk assessments have been conducted in the vicinity of abandoned or currently operating facilities. In addition, examples of significant and direct health impacts from hazardous wastes are limited (examples are Minimata disease, Itai-itai, and pesticide poisonings). While the risks to human

health are difficult to calculate, some damages can be more clearly associated with hazardous wastes, such as the loss of value in contaminated land and the loss of productive water supply aquifers.

Uncertainty about risks causes uncertainty about regulatory benefits. The current limited knowledge of the chronic health effects of low exposure to many hazardous wastes makes it virtually impossible to estimate the benefits of reducing the impacts. One economic justification of a hazardous waste management program is the benefits in terms of future cleanup costs avoided. However, given the uncertainty about the location and extent of future damage and about the rules for the level of cleanup that might be required, the estimation of benefits is extremely uncertain. In fact, numbers from the U.S. experience show that benefits in these cases are more often low than high. It is difficult to compare hazardous wastes with other environmental problems for which it is easier to estimate benefits in terms of overall reduction of risk to public health.

An economics-based approach to managing hazardous wastes takes advantage of incentives to reduce risks while balancing the costs and benefits of doing so. One way of achieving this is to tailor requirements to reflect the wide variations in the risks of different waste types, disposal sites, and exposure conditions (rather than regulating facilities at the same level), and concentrating resources on the worst risks first.

Siting: A Critical Issue

The location of a hazardous waste facility requires careful consideration of a wide range of technical, economic, and social factors. It is often a controversial process because of local opposition. Many schemes have been delayed or abandoned because of difficulties in obtaining an acceptable site. The government obviously has a role in leading the siting process and ensuring that clear information is provided, that there is a process for taking local concerns into account, and that realistic commitments are made about control and monitoring of operations. An environmental assessment will normally be required, depending on the type, scale, and location of facility being proposed.

Financing and Funding

Proper management, treatment, and disposal of hazardous wastes are costly; and there are strong incentives for generators and transporters to avoid paying the real costs. In practice, it has normally been difficult to implement a realistic system of charges for hazardous wastes without a strong enforcement regime, which is itself rare. The consequence is that it is almost impossible, especially in the early stages of a new system, to generate an adequate revenue stream to cover the costs of the necessary facilities. In the absence of a reliable revenue stream, it is difficult to finance the capital investment required. The lack of an effective system for imposing costs on generators also undermines any financial incentive to adopt waste reduction measures. International experience indicates that integrated hazardous waste treatment facilities are typically not commercially viable except in well-regulated industrial countries.

Without a credible government-driven market for hazardous waste management infrastructure, it is difficult to expect investment by industry or the financial sector in this area. In this case, a transition period of blended incentives (“carrots”) and disincentives (“sticks”) can be used, as has been the case in many OECD countries and, more recently, in Asia. Subsidized seed capital and targeted credit, for a limited period of time, can help ease the adjustment of industries to a tighter regulatory environment as they face one-time adjustment costs and can strengthen the environmental services industry’s ability to provide services for hazardous waste management.

Role of the Private Sector

The overall design and implementation of a hazardous waste management program is normally a government function, but the private sector can play a major role in the provision and operation of the necessary facilities. Transport of wastes is nearly always a private sector function, although careful control and licensing by the relevant authorities may be required.

The design, construction, and operation of treatment and disposal facilities are frequently

carried out by the private sector. However, particularly in the early stages of a hazardous waste management program, government involvement may be required in the siting and initial development of key facilities. In most cases, some practical demonstration of government commitment to regulation of waste generators and haulers may be required to convince the private sector to invest in major facilities.

Remediation

A national or regional hazardous waste management plan should identify existing hazardous waste dumps, illegal sites, and areas contaminated by toxic or hazardous materials. However, the costs of remediation can be high, and careful assessments of the benefits should be carried out before any commitments are made to spend public funds on cleanup.

Experience with high cleanup standards in the United States and the Netherlands has shown that the result can be very costly projects without correspondingly high benefits. An alternative approach is to design cleanup to meet the requirements for realistic subsequent land uses.

Scale and Costs of Facilities

Some indicative values can be given for the scale and cost of typical facilities.

The construction costs for a secure hazardous waste landfill will obviously depend on the size, but a facility capable of accepting 100,000 metric tons (t) per year would probably cost US$3 million–$8 million for initial construction. The planning, siting, and permitting processes can add 10–20% to this cost.

The economic minimum size for an integrated facility (treatment, incineration, and landfill) is probably of the order of 20,000–40,000t / year capacity. Such a facility would cost US$20 million–$50 million to construct (say US$1,000–$1,500 per metric ton capacity) and would require revenues of perhaps US$500–$1,000 / t for profitable operation. In practice, such facilities are not usually commercially successful outside well-regulated industrial countries. For example, Hong Kong (China) has developed a successful large, high-technology facility, but it operates at a low level of cost recovery.

More successful approaches are based on simpler facilities to deal with a somewhat limited range of wastes. One such site with a stabilization system and secure landfill, together with the facilities for burning waste oil in a cement plant, is reported to have cost US$20 million for a total capacity of 70,000t / y (about US$300 per metric ton capacity).

A Road Map

Development of a hazardous waste management system is a complex and time-consuming task, but experience suggests a number of steps:

- There must be the political will to impose the costs on the generators, through enforcement or other persuasive mechanisms.
- Start by dealing with the simpler problems for which there are well-established technical solutions
- Address the siting problem early—it is very difficult for the private sector to obtain sites without government involvement in the selection process. Where possible, use existing sites, as long as they are technically and environmentally acceptable.
- Be skeptical about projections of quantities; design a flexible system. Support waste reduction and recycling efforts.
- Focus on prevention of dumping; remediation of contaminated sites is usually a second priority.

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