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Guides to Pollution Prevention

Non-Agricultural Pesticide Users

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GUIDES TO POLLUTION PREVENTION:
Non-Agricultural Pesticide Users

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NOTICE

This guide has been subjected to U.S. Environmental Protection Agency peer and administrative review and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

This document is intended as advisory guidance only to non-agricultural pesticide users in developing approaches for pollution prevention. Compliance with environmental and occupational safety and health laws is the responsibility of each individual business and is not the focus of this document.

Worksheets are provided for conducting waste minimization assessments of non-agricultural pesticide firms. Users are encouraged to duplicate portions of this publication as needed to implement a waste minimization program.

FOREWORD

This guide provides an overview of non-agricultural pesticide use and presents options for minimizing waste generation through source reduction and recycling. Non-agricultural pesticide users are defined, for the purposes of this manual, as lawn and garden; forestry, tree and shrub; sanitary; structural; nursery; and greenhouse pest control services. The industry is made up mostly of small businesses or franchises; and, as a result, individual locations do not generate large quantities of waste, although some of the waste can be acutely toxic.

Waste generated by non-agricultural pesticide users is a result of pesticide storage, distribution, and mixing and equipment cleaning. The major waste streams are used protective clothing, empty pesticide containers, rinsate from cleaning containers and equipment, surplus inventory, and pesticide dust and water droplets, as well as waste resulting from unnecessary application of pesticides to non-targeted areas or at excessive rates to targeted areas. (Pesticide application sites and rates must comply with label directions.) Reducing the amount of this waste will benefit both the non-agricultural pesticide application industry and the environment.

ACKNOWLEDGMENTS

This guide is based in part on waste minimization assessments (*Waste Audit Study: Non-agricultural Pesticide Application Industry*) conducted by Tetra Tech, Inc., San Francisco, California, for the California Department of Toxic Substances Control and the U.S. Environmental Protection Agency (EPA). Battelle Memorial Institute edited and expanded the California waste minimization assessment report under subcontract to EPA (USEPA Contract 68-C0-0003). Battelle personnel contributing to this guide include Bob Olfenbuttel, work assignment manager; Leslie Hughes, task leader; Larry Smith, Illa Amerson, Jody Jones, and Tom McClure, technical engineers; and Bea Weaver, production editor. Other contributors include Teresa Harten (EPA), Christine Rugen (Appropriate Technology Transfer for Rural Areas), and Matthew F. Holmes (Consultant).

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SECTION 1
INTRODUCTION

This guide is designed to provide non-agricultural pesticide users with waste minimization options. It also provides worksheets for carrying out waste minimization assessments. The guide is intended for use by the non-agricultural pesticide industry and regulatory agency representatives, industry suppliers, and consultants.

In the following sections of this manual you will find:

- A profile of the non-agricultural pesticide application industry and the processes used in it (Section 2)
- Waste minimization options for the industry (Section 3)
- Waste minimization assessment guidelines and worksheets (Section 4)
- Appendices, containing
  - Case studies of waste generation and waste minimization practices in the industry
  - Where to get help: additional sources of information.

The worksheets are the result of updating and expanding assessments of non-agricultural pesticide application services in California (DHS 1991). Waste generation and management practices were surveyed, and potential waste minimization options were identified.

Overview of Waste Minimization

Waste minimization is a policy specifically mandated by the U.S. Congress in the 1984 Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act (RCRA). As the federal agency responsible for writing regulations under RCRA, the U.S. Environmental Protection Agency (EPA) has an interest in ensuring that new methods and approaches are developed for minimizing hazardous waste and that such information is made available to the industries concerned. This guide is one of the approaches EPA is using to provide industry-specific information about hazardous waste minimization. The options and procedures outlined can also be used in efforts to minimize other wastes generated in a business.

In the working definition used by EPA, waste minimization consists of source reduction and recycling. Of the two approaches, source reduction is usually considered preferable to recycling. While a few states consider treatment of waste an approach to waste minimization, EPA does not, and thus treatment is not addressed in this guide.

Facility Planning for Pollution Prevention

With the Pollution Prevention Act of 1990, the U.S. Congress established pollution prevention as a "national objective." To encourage the adoption of pollution prevention activities in industry, EPA published the *Facility Pollution Prevention Guide* (USEPA 1992) as a successor to the *Waste Minimization Opportunity Assessment Manual* (USEPA 1988), which was a general manual for waste minimization in industry. The *Waste Minimization Opportunity Assessment Manual* described how to conduct a waste minimization assessment and develop options for reducing hazardous waste generation at a facility.

The *Facility Pollution Prevention Guide* expands the scope of the *Waste Minimization Opportunity Assessment Manual* to emphasize "multimedia" pollution prevention. It explains the management strategies needed to incorporate pollution prevention into company policies and how to establish a company-wide pollution prevention program, conduct assessments, implement options, and make the program an ongoing one. It is intended to help small- to medium-sized production facilities develop broad-based, multimedia pollution prevention programs. Methods of evaluating, adjusting, and maintaining the program are described. Later chapters deal with cost analysis for pollution prevention projects and with the roles of product design and energy conservation in pollution prevention. Appendices consist of materials that will support the pollution prevention effort such as assessment worksheets and sources of additional information.

The method described in the *Waste Minimization Opportunity Assessment* (WMOA) *Manual* is generally the same as the method for carrying out facility pollution prevention planning. It is a systematic procedure for identifying ways to reduce or eliminate waste. The four phases of a waste minimization opportunity assessment are planning and organization, assessment, feasibility analysis, and implementation. The steps involved in conducting a waste minimization assessment are outlined in Figure 1 and presented in more detail below. Briefly, the assessment consists of a careful review of a facility's operations and waste streams and the selection of specific areas to assess. After a particular waste stream or area is established as the WMOA focus, a number of options with the potential to minimize waste are developed and screened. The technical and economic feasibility of the selected options are then evaluated. Finally, the most promising options are selected for implementation.

PLANNING AND ORGANIZATION PHASE

Essential elements of planning and organization for a waste minimization program are getting management commitment for the program, setting waste minimization goals, and organizing an assessment program task force.

ASSESSMENT PHASE

The assessment phase involves a number of steps:

- Collect process and facility data
- Prioritize and select assessment targets
- Select assessment team
- Review data and inspect site
- Generate options
- Screen and select options for feasibility study.

Collect Process Data

The waste streams at a facility or in a service's operations should be identified and characterized. Information about waste streams may be available in hazardous waste manifests, National Pollutant Discharge Elimination System (NPDES) reports, routine sampling programs, and other sources.

Developing a basic understanding of the processes that generate waste is essential to the WMOA process. Flow diagrams should be prepared to identify the quantity, types, and rates of waste generating processes. Also, preparing material balances for the different processes can be useful in tracking various process components and identifying losses or emissions that may have been unaccounted for previously.

Prioritize and Select Assessment Targets

Ideally, all waste streams in an operation or at a facility should be evaluated for potential waste minimization opportunities. With limited resources, however, the operations manager may need to concentrate waste minimization efforts for a specific operation. Such considerations as quantity of waste, hazardous properties of the waste, regulations, safety of employees, economics, and other characteristics need to be evaluated in selecting target streams or operations.

Select Assessment Team

The team should include people with direct responsibility for and knowledge of the particular waste stream or operation being assessed. Equipment operators and people involved in routine waste management should not be ignored.

Review Data and Inspect Site

The assessment team evaluates process data in advance of the inspection. The inspection should follow the target process from the point where raw materials enter to the point where products and wastes leave. The team should identify the suspected sources of waste. This may include the production process, maintenance, operations, and storage areas. The inspection may result in the formation of preliminary conclusions about waste minimization opportunities.

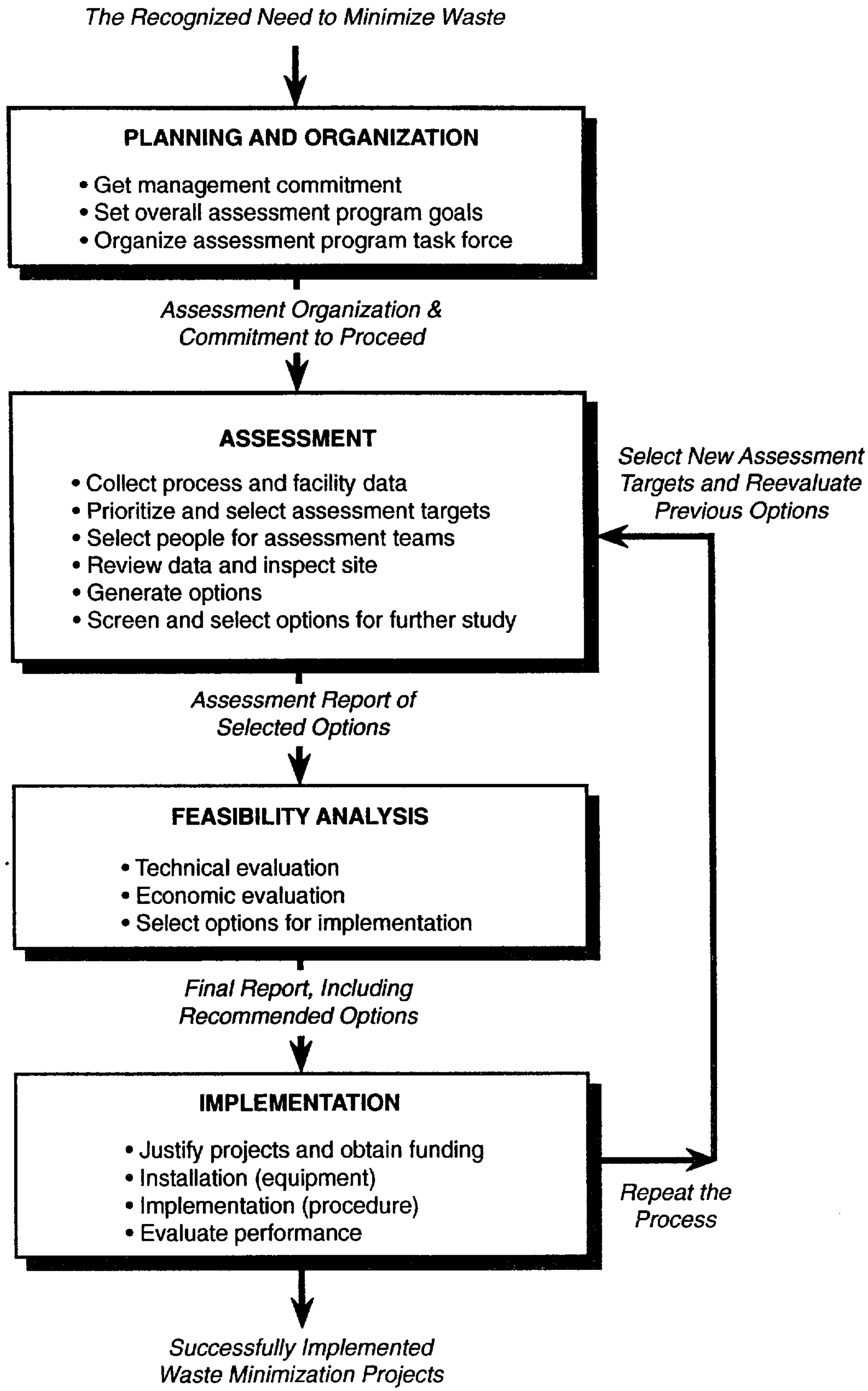

Figure 1. The Waste Minimization Assessment Procedure

Full confirmation of these conclusions may require additional data collection, analysis, and/or site visits.

Generate Options

The objective of this step is to generate a comprehensive set of waste minimization options for further consideration. Since technical and economic concerns will be considered in the later feasibility step, no options are ruled out at this time. Information from the site inspection, as well as trade associations, government agencies, technical and trade reports, equipment vendors, consultants, and plant engineers and operators may serve as sources of ideas for waste minimization options.

Both source reduction and recycling options should be considered. Source reduction may be accomplished through good operating practices, technology changes, input material changes, and product changes. Recycling includes use and reuse of water, solvents, rinsates, and other recyclable materials, where appropriate.

Screen and Select Options for Feasibility Study

This screening process is intended to select the most promising options for a full technical and economic feasibility study. Through either an informal review or a quantitative decision-making process, options that appear marginal, impractical, or inferior are eliminated from consideration.

FEASIBILITY ANALYSIS PHASE

An option must be shown to be technically and economically feasible to merit serious consideration for adoption at a facility. A technical evaluation determines whether a proposed option will work in a specific application. Both process and equipment changes need to be assessed for their overall effects on waste quantity and product quality. A major concern is the impact of any proposed changes on the product license. Minor changes may be implemented rather easily, but major changes may require review and approval of the revised process. The time required for this activity may make some options impossible. Further, many pesticide users are providing services to property owners who may need to be educated before a new technique can be adopted.

An economic evaluation is carried out using standard measures of profitability, such as payback period, return on investment, and net present value. As in any project, the cost elements of a waste minimization project can be broken down into capital costs and operating costs. Savings and changes in revenue and waste disposal costs also need to be considered, as do present and future cost avoidances. In cases of increasingly stringent government requirements, actions that increase the cost of production may be necessary.

IMPLEMENTATION PHASE

An option that passes both technical and economic feasibility reviews should be implemented. The project can be turned over to the appropriate group for execution while the WMOA team, with management support, continues the process of tracking wastes and identifying other opportunities for waste minimization. Periodic reassessments may be conducted to see if the anticipated waste reductions were achieved. Data can be tracked and reported for each implemented idea in terms such as pounds of waste per production unit. Either initial investigations of waste minimization opportunities or the reassessments can be conducted using the worksheets in this manual.

References

DHS. 1991. *Waste Audit Study: Non-Agriculural Pesticide Application Industry.* Prepared by Tetra Tech, Inc. for Alternative Technology Section, Toxic Substances Control Division, California Department of Health Services.

USEPA. 1992. *Facility Pollution Prevention Guide.* U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC, EPA/600/R-92/088.

USEPA. 1988. *Waste Minimization Opportunity Assessment Manual.* U.S. Environmental Protection Agency, Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, EPA/625/7-88/003.

SECTION 2
PROFILE OF THE NON-AGRICULTURAL PESTICIDE APPLICATION INDUSTRY

Industry Description

The non-agricultural pesticide application industry is defined for the purposes of this manual as lawn and garden services (Standard Industrial Classification 0782), ornamental shrub and tree services (SIC 0783), forestry services (SIC 0851), sanitary services (SIC 4959), disinfecting and pest control services (SIC 7342), and ornamental floriculture and nursery products (SIC 0181). Firms providing these services include landscape maintenance firms, commercial nurseries, and structural pest control firms, as well as government agencies. Many of these firms specialize in the application of pesticides (e.g., pest control services), while for others pesticide application is secondary. Application of pesticides to field crops is not considered in this manual. Further, this manual is not intended as a comprehensive guide to pollution prevention in the non-agricultural pesticide industry. It is an introduction designed to assist pesticide users who want to begin to assess opportunities for waste minimization.

Non-agricultural application of pesticides represents a sizable portion of the demand for and use of pesticides nationwide. Private companies or local, regional, and state agencies either perform their own pest control activities or contract pest control services to others. Industry data indicate that $853,593,000 was spent on non-crop pesticides in 1989. This was 16 percent of the total U.S. sales of pesticides in 1989 (Ernst and Young 1989). An analysis of 1989 pesticide sales in the United States by type and end use is provided in Table 1.

Process Description

The non-agricultural pesticide application industry must safely and efficiently control a variety of pests in many environments. As a result, the industry has evolved a broad range of formulations and application techniques to serve customer needs.

Typical pesticide application activities include

- Storing and distributing pesticide products
- Mixing and formulating pesticides
- Applying pesticides
- Cleaning equipment
- Managing waste.

Formulation types and handling procedures for conventional pesticides are given in Table 2.

Chemical pesticides may be formulated as dusts, emulsifiable concentrates, granules, solutions, or wettable powders. Emulsifiable concentrates are produced by dissolving the pesticide in a solvent and adding emulsifiers. Granules are produced by diluting the pesticide with inert and functional ingredients. Wettable powders are produced by applying pesticides to clay particles with a wetting agent. Dusts are frequently used to apply insecticides and fungicides, but surfactants are usually used to apply herbicides.

Surfactants are produced as detergents, dispersants, emulsifiers, spreading agents, or wetting agents. While many pesticides cannot be easily mixed in water, surfactants make pesticides highly water soluble.

Because pesticides are frequently obtained as concentrates, the user is responsible for safely (1) storing the material; (2) transferring, mixing, and applying the material; and (3) recycling or disposing of excess concentrate, mixtures, rinsate, and containers. The user is also responsible for preventing pesticide drift.

Waste Description

Major waste streams within this industry include used protective clothing, empty pesticide containers,

Table 1. 1989 U.S. Pesticide Sales by Type and End Use
Composite Analysis of All Reporting Companies
(in thousands)

	Herbicides	Insecticides	Fungicides	Other	Total[a]	Percent of U.S. Sales
CROP USE	$3,043,700	$897,692	$315,832	$213,605	$4,470,829	83.97
NON-CROP USE						
Forestry	46,843	4,549	0	0	51,392	0.97
Industrial						
Weed Control	107,325	0	(D)	(D)	128,837	2.42
Brush Management	43,451	0	0	0	43,451	0.82
Turf, Nursery Ornamentals	94,680	52,926	65,439	15,303	228,348	4.29
Home & Garden	75,557	59,537	(D)	(D)	137,090	2.57
Pesticide Contract Operators	0	127,429	0	27,634	155,063	2.91
Public Health	0	(D)	0	(D)	12,394	0.23
Other Non-crop	67,834	(D)	(D)	(D)	97,018	1.82
Categories Not Shown Above[b]	0	21,160	13,587	30,339	(b)	N/A
Subtotal	$435,690	$265,601	$79,026	$73,276	$853,593	16.03
GRAND TOTAL	$3,479,390	$1,163,293	$394,858	$286,881	$5,324,422	100.00

(D) Not shown to avoid disclosure of individual company data.
(a) Total U.S. pesticide sales by end use.
(b) Total of categories shown as (D) value is included in total by end use.

Source: Ernst and Young 1989.

rinsate from cleaning containers and equipment, surplus inventory, surplus field mixtures, plastic tarps used in structural fumigation, pesticide dust and water droplets, and pesticide residues in soil. In a broader sense, pesticide wastes also include those pesticides unnecessarily or over-applied to targeted areas and pesticides mistakenly or inadvertently applied to non-targeted areas, which is illegal. The activities and types of waste generated by individual segments of the non-agricultural pesticide application industry are discussed below.

LAWN AND GARDEN SERVICES

Lawn and garden services include lawn care, cemetery upkeep, roadside right-of-way, and golf course care. This is probably the largest of the segments of the non-agricultural pesticide application industry addressed in this guide, with most of the firms involved in landscaping and lawn maintenance. A wide variety of liquid, powder, and granular pesticides are used by lawn services. Liquids and wettable powders are applied using wick applicators, knapsack

Table 2. Common Pesticide Formulation Types and Handling Procedures

Formulation Type	Special Handling or Storage Procedures	Signs of Deterioration	Application Procedures
Oil sprays and liquids	Avoid storing in extreme temperature conditions	Milky coloration does not occur when water is added	Sprayers
Wettable powders	Avoid high humidity or contact with ground	Lumping occurs and powder will not suspend in water	Sprayers
Dusts	Avoid using during windy conditions	Excessive lumping	Dust fogs using hand- or power-operated blowers
Granulars	Store in dry areas	Excessive lumping	Manually or using mechanical spreaders
Aerosols	Avoid using during windy conditions	Aerosol nozzle becomes obstructed	Pressurized sprayers
Emulsifiable concentrates	Store in dry areas	Milky coloration does not occur when water is added; sludge formation	Sprayers

sprayers or truck-mounted spraying equipment, powders and dusts are applied by hand or with powered blowers, and granules are applied by hand or with mechanical spreaders. Wastes include pesticide dust and droplets, used pesticide containers, outdated or canceled products, protective clothing, rinse water, spills, and unused or deteriorated pesticide.

FORESTRY AND TREE AND SHRUB SERVICES

A variety of chemical pest control techniques are used to provide ornamental tree and shrub and forestry services. Tree protection chemicals are generally formulated as liquid concentrates, solutions, and emulsifiable concentrates or powders that are sprayed on trees when maintenance practices do not sufficiently control pests. Spreaders, stickers, and surfactant additives keep chemicals in suspension and improve their ability to stick to and wet foliage. The wastes from these activities include airborne droplets, used pesticide containers, outdated or canceled products, protective clothing, rinse water, spills, and unused or deteriorated pesticide.

SANITARY SERVICES

Sanitary services relevant to the non-agricultural pesticide industry include mosquito eradication and malaria control. Mosquito eradication frequently is coordinated through mosquito abatement districts, vector control districts and programs, and pest abatement districts. If mosquitoes are allowed to become adults, wide areas must be sprayed. Therefore, an increasing number of mosquito control agencies concentrate their efforts on the aquatic mosquito larvae and pupae. Wastes generated in this segment of the industry include airborne droplets, used pesticide containers, outdated or canceled products, protective clothing, rinse water, and unused pesticide.

DISINFECTING AND STRUCTURAL PEST CONTROL SERVICES

Firms that provide disinfecting, exterminating, and fumigating services rid buildings of moths, cockroaches, termites, other insects, rodents, wood-decaying fungi, and other pests. Structural pest control services use a variety of synthetic pyrethroid, organophosphate, and methylcarbamate insecticides and bait to control pests that attack and destroy buildings, clothing, stored food, and manufactured and processed goods. Bait containing diphacinone as an active ingredient is commonly used for rat and mouse eradication. Wastes generated in this segment of the industry include pesticide residues, outdated products, uneaten bait, canceled products, unused or deteriorated pesticide, spills, and empty containers.

ORNAMENTAL FLORICULTURE AND NURSERY PRODUCTS

The ornamental floriculture and nursery products segment of the industry is engaged primarily in producing ornamental plants and other nursery products, such as bulbs, florists' greens, flowers, shrubbery, flower and vegetable seeds and plants, and sod. These products may be grown under cover (greenhouse, frame, cloth house, lath house) or outdoors. Pests include aphids, scales, beetles, mites, rats, squirrels, birds, snakes, fungi, bacteria, viruses, and weeds. Wastes generated include used pesticide containers, outdated or canceled products, protective clothing, rinse water, spills, and unused or deteriorated pesticide.

Reference

Ernst and Young. 1989. *National Agricultural Chemicals Association Industry Profile*, Washington, DC, p. 7.

SECTION 3
WASTE MINIMIZATION OPTIONS FOR NON-AGRICULTURAL PESTICIDE APPLICATION

Introduction

Several source reduction and recycling options are available to minimize waste from non-agricultural pesticide use. If waste cannot be reduced or eliminated through source reduction practices, recycling is the next best solution. One of the best ways of minimizing pesticide waste is to follow pesticide label instructions. In addition, it may be possible to minimize pesticide use through integrated pest management.

In many operations, the quantity or toxicity of the hazardous waste can be significantly reduced through relatively simple changes in process management. In contrast to agricultural and manufacturing industries, non-agricultural pesticide services frequently do not have control over the property to which they apply pesticides. However, the options suggested in this manual may be offered as recommendations to property owners if they cannot be implemented directly.

Non-agricultural pesticide users should keep abreast of improved technology in hazardous waste reduction and management. Information sources include trade journals, chemical and equipment suppliers, equipment expositions, conferences, and industry association newsletters. Advancing technology can provide economical alternatives that can lead to reduced waste generation and a more cost-efficient operation.

Hazardous waste, worker health and safety, and other environmental and safety requirements change continually at the federal, state, and local levels. Non-agricultural pesticide users must keep up to date on these changes and maintain flexibility regarding waste management options.

Waste Minimization Options

- **Integrated Pest Management**
- **Inventory Management**
- **Proper Mixing**
- **Product Substitution**
- **Container Waste Minimization**
- **Efficient Application**
- **Good Housekeeping Practices**

Source Reduction and Recycling Options

Integrated pest management should be the guiding principle for implementing waste reduction techniques. In addition to integrated pest management, inventory control, proper pesticide mixing, product substitution, container waste minimization, efficient application of pesticides, and good housekeeping practices will reduce waste.

INTEGRATED PEST MANAGEMENT

Integrated pest management (IPM) is an approach to waste management that considers the whole ecosystem in determining the best methods for controlling pests. Factors such as prior pest history, plant growth and development, and pest monitoring information are considered when developing a pest management plan. IPM pest control strategies are designed to require minimal use of pesticides and emphasize solutions that will minimize harm to the ecosystem, human health, and the environment (Brett 1985).

By using a range of approaches (including physical, biological, and chemical methods) for controlling pests, IPM commonly reduces the need for chemical pesticides by between 50 percent and 90 percent. An added advantage of IPM is that, with decreased exposure to chemical pesticides, pests are less likely to become resistant. When chemical pesticides must be used, they are thus more likely to be effective.

Much has been written about various IPM programs within the non-agricultural sector, including descriptions of programs used for controlling pests in forests and parks (Daar 1987, Widin 1987, Nielsen 1989, Ticehurst and Finley 1988, and Collman 1989), greenhouses (Helyer and Payne 1986), and commercial lawn care (Leslie and Metcalf 1989). The success of IPM in reducing waste and controlling pest populations makes it clear that this process should be a fundamental part of every waste management program.

The six steps common to all IPM plans (shown in Figure 2) can be used to determine appropriate treatment methods and time frames (Srinath 1986, Bechtol 1989). Planning for a large project (forest or park treatment) should include an evaluation of staff resources and training before beginning Step 1. Staff must be available and trained to identify critical pests.

After pests have been identified and the ecosystem defined (Steps 1 and 2), pest populations must be assessed (Step 3). Pest population survey methods should be tailored to the size of the operation and the nature of the pest. In many cases, visual observation of plant populations or a survey of insect populations with a hand lens will allow accurate assessment of pest problems. A sticky trap has also been developed to monitor greenhouse pests (Larsen 1986). Pheromone traps have proven an important tool for insect population assessment in larger areas. Sex pheromones for over 1,000 insects have been identified. Data from traps can be used to locate sources of infestation, as well as determine the timing of control methods. Pheromone traps also serve to identify the pest and to measure the efficacy of control programs following pesticide application. As a result, fewer applications of pesticides are necessary, and the area requiring treatment is reduced.

Based on the information obtained by monitoring pest populations, the cost effectiveness of a pest management program can be determined (Step 4). If such a program seems necessary, options should be developed (Step 5) and evaluated (Step 6). These steps make IPM a practical strategy for alleviating pest problems with a minimum of pesticide waste. The goal of pest management is not necessarily to eliminate pests, but to maintain them at acceptable levels. By following the six steps of integrated pest management, pest populations can be brought within tolerable numbers.

As the integrated pest management approach has developed, specific methods have been established for several industries. In the plant care field, the concept of plant health care (PHC) has been given increased emphasis. In contrast to IPM, PHC focuses on plant health rather than pests. A few examples of IPM and PHC are mentioned below.

Lawn and Garden Services

IPM and PHC methods that can be used by lawn and garden services include selecting plants resistant to the pests prevalent in an area, modifying the habitat to suit the plants by mulching or decreasing plant density, and continuously evaluating a plant's needs. Fertilization, pruning, and watering practices can be changed as needed. Pests can be removed manually; or traps, baits, and barriers can be used (Helyer and Payne 1986). Natural enemies can be introduced, or microbial insecticides can be applied if these measures do not work. Chemical control methods are used as a supplement if needed.

Implementing IPM and PHC methods for home lawns and gardens is relatively simple. However, because of the extent of the turfgrass in public areas, planning the appropriate strategy becomes more complex.

Turfgrass covers more than 25 million acres of the United States in the form of home lawns, golf courses, parks, athletic fields, schools, and other areas (Wu and Harivandi 1988). Interest has been increasing on the part of the public and the turfgrass industry to manage turf in a way that requires a minimum of pesticides and fertilizers (Schultz 1989, Bio-Integral Resource Center 1987, Bennett and Owens 1986, and Ware

Six Steps are Common to Integrated Pest Management Plans

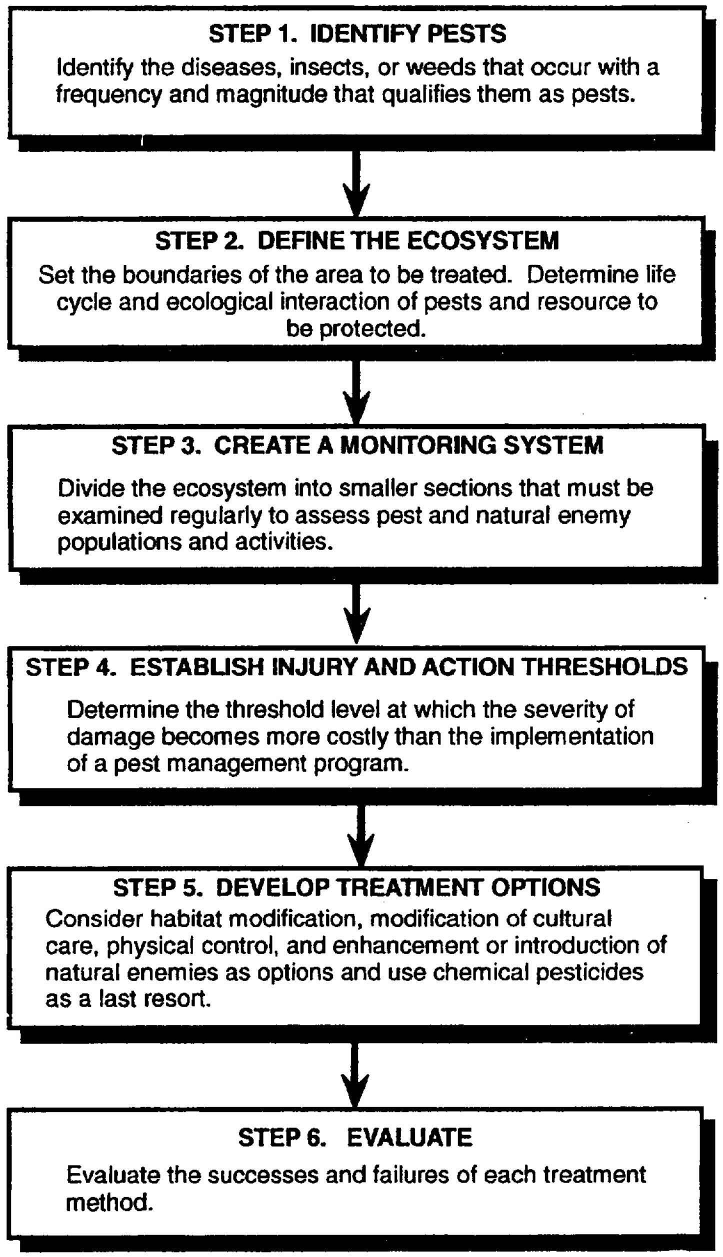

Figure 2. Six Steps Common to All IPM Plans

1988). The Iowa State University Extension Service has published several turfgrass management brochures containing guidelines for maintaining healthy turf (Iowa State University, 1991a, b, and c).

The key to low-input turf management is reducing plant stress through practices that create healthy turf that is resistant to disease and insect pressure. Turf health care is a key element of a successful IPM program for lawns and gardens. The goal of turf health is reducing plant stress to help a plant resist disease, insect, and weed pressures. Providing an optimum environment for establishing and growing turfgrass should be the first objective of any lawn care program. Evaluating and improving the soil condition and establishing and selecting the proper turfgrass variety should be the starting point. Having the soil tested provides important information about the soil's pH and its level of phosphorus, potassium, and minor elements. Proper fertilization, aeration, irrigation, and mowing are also factors that affect turf health and quality.

For example, it is important to avoid excessive applications of nitrogen to turf. Too much nitrogen reduces turf drought tolerance and increases thatch production, susceptibility to disease, and invasion by weeds.

Irrigation should be managed closely to reduce disease, insect, and weed problems. Deep, less frequent irrigations encourage healthy root systems that are drought- and pest-resistant. Shallow irrigation results in shallow root systems and turf that more easily succumbs to pest problems. Excessive water also creates areas of stagnant water, promoting conditions favorable for mosquito growth. In arid areas, selecting a turf species that performs well with minimal water input is important (Wu and Harivandi 1988).

When selecting a turfgrass species, several factors should be considered. The turfgrass should be adaptable to the shade, moisture, and fertility of the location. Varieties tolerant to diseases such as leaf spot, dollar spot, and Fusarium blight should be used if possible. The turfgrass varieties Allstar and Repell (both perennial ryes) and some tall fescue varieties contain a fungus that gives the turf resistance to surface-feeding insects such as sod webworms and chinch bugs.

Mowing practices also greatly influence turf health. Grass that is cut too short is less vigorous, and consequently is more susceptible to disease and insect problems and to bare spots that allow weed encroachment (Emmons 1984). In general, temperate turfgrass should be mowed to a height of two to three inches, no more than one-third of the surface area should be cut off at a time, and the clippings should be left on the lawn to maintain nutrients (Clark 1987). Subtropical turfgrasses, grown in the Western and Southern states, should be mowed to a height of 3/4 inch to 1-1/2 inches.

Common turf insect pests include several beetle species: white grubs (the larval stages of several beetle species, including the Japanese beetle), European chafers, Asiatic garden beetles, and green June beetles. Chinch bugs, sod webworms, and mole crickets may also cause problems. Practices that promote healthy turf go a long way toward reducing these pests. A healthy turf can withstand up to eight to ten beetle grubs per square foot and is also much more tolerant of chinch bug damage (Clark 1987). Several control options exist for managing turf insect pests. Entomogenous (insect feeding) nematodes have been used against several beetle species and mole crickets. *Bacillus thuringiensis* is used against sod webworms. Irrigation is used to solve chinch bug outbreaks. The turfgrass varieties Allstar and Repell (both perennial ryes) and some tall fescue varieties contain a fungus that gives the turf resistance to surface-feeding insects such as sod webworms and chinch bugs.

Forestry and Tree and Shrub Services

Fully integrated pest control for forestry and tree and shrub services can include behavioral, physical, biological, and chemical methods. Bacteria, viruses, and pheromone mating disruption products have been demonstrated to control pests such as the codling moth and oriental fruit moth (Ridgeway et al. 1990).

Population monitoring and biological pesticides have been used to predict and control pest populations in forests. *Bacillus thuringiensis*, toxic to a narrow range of lepidoptera, has proven effective against the gypsy moth and spruce budworm in Western forests (Bernier et al. 1990). New products for pest control include pheromone mating disruption products for defoliators and semiochemicals that act as growth regulators to prevent maturation and reproduction. Mass trapping of bark beetles has also shown some success.

Often pest outbreaks on a forest-wide scale are linked to environmental stress from drought and other factors. Non-chemical strategies to improve stand resistance to insects include thinning and removal of diseased and damaged trees. Watering and fertilization, when practical, can also improve tree vigor. Long-term strategies include diversifying the age classes of forest stands and managing for persistent species.

Sanitary Services

Mosquito IPM has outpaced many other sectors of pest control because of the need to prevent outbreaks of disease (such as encephalitis and malaria) carried by mosquitoes. Sophisticated operations exist on small and large scales throughout the country.

A traditional mosquito control approach, which uses fogging machines to apply oil solutions directly to marshes and standing water, contributes significantly to localized air pollution. As an alternative, IPM begins by identifying sources of mosquito production. Often these sources can be eliminated. Examples include removing old tires and other objects that collect water and improving drainage to remove seasonal breeding sites. Many breeding sites are wetlands that are important to fish and wildlife. Because these areas may be protected by state and federal law, proper land-use authorities should be consulted prior to any drainage improvement work.

When breeding sites cannot be removed, dip-netting is used to identify and quantify the pest population. Biological control methods such as predatory insects and mosquito fish can be used where practical. When breeding sites are only present seasonally, larvicides may be required.

Mosquitoes in the larval stage can be controlled with *Bacillus thuringienis israelensis* (Bti) (Knepper et al. 1991). Bti kills only the larval stage of the mosquito and does not affect other wildlife or beneficial insects, pets, or people. Bti comes in granular, powder, and liquid formulations. Methoprene, an insect growth regulator, mimics a natural insect hormone and prevents larvae from entering the pupal stage. Methoprene readily degrades into non-toxic products. Both of these products are available in long-lasting formulations allowing for fewer applications.

Following larvicide application, production sources should be measured again for larvae or pupae. If larvae are present, larvicide can be reapplied. If pupae are present, surface coating surfactants can be used to inhibit the ability of the adult mosquito to emerge from the pupal case. Narrow-spectrum surfactants should be used. As a last resort, when adult mosquitoes are abundant and need to be controlled, resmethrin, a synthetic pyrethroid, can be sprayed as an ultrafine fog adulticide. Resmethrin is toxic to non-target aquatic organisms, but has a relatively short active lifetime (Holmes 1992).

Disinfecting and Structural Pest Control Services

Pests in buildings are managed largely through preventive measures which, if taken, should greatly reduce the need for actual pest control. Sanitation is key. Good sanitation involves sealing and storing food properly, cleaning up crumbs or spills, and disposing garbage properly in a covered and sealed container. Structural repairs may also be necessary to prevent a pest problem. The roof and walls of a building should be checked for cracks and signs of water damage or decay and repaired. Cement aprons and channels can be installed to prevent moisture-seeking insects from becoming established in water accumulating near foundations. Cracks around windows, doors, and the foundation should be sealed with caulking. Screens should be installed or replaced as necessary. Where preventive measures fail, several control measures are available. Heat treatments and sorptive dusts such as silica aerogels blown into wall voids are sometimes effective. Non-pesticidal controls such as glue boards, snap and pheromone traps, and insect electrocutors should be tried before chemical pesticides are used.

Ornamental Floriculture and Nursery Products

Pests of indoor plants can be controlled by carefully controlling the environment. Care should be taken not to introduce pests into the indoors. Barriers can be constructed to exclude crawling pests such as snails and slugs. Regulating moisture and heat is also an effective pest control measure. For example, providing adequate moisture and protecting plants from heat reduces mite infestations. Predatory mites, insecticidal soaps, and horticultural oil are also effective against pest mites. Leaves infested with aphids can be pruned, and natural enemies such as green lacewings are commercially available to control aphids. Moderating the amount of nitrogen in fertilizer reduces infestations of aphids, scale, and whiteflies. Hand-held vacuums can be used to suck up whiteflies.

IPM for plants grown indoors is well established. Careful integration of pest control strategies must be based on the number and type of plants grown. Focusing on one pest can disrupt the environment and create another pest outbreak. Most operations employ both biological and chemical control techniques, but favor introducing natural enemies. For example, red spider mites and whiteflies are controlled by the predators Phytoseiulus and Encarsia. Leafminers can be removed by introducing ecto- and endoparasites during warm weather. Caterpillars are managed by applying the HD-1 strain of *B. thuringiensis*. Steinernematid and Heterorhabditis, which like dark, moist conditions, can be used to control mushroom flies.

The integration of chemicals into control programs may be necessary because there are some pests for which biological control options have not been developed (Steiner and Elliot 1983). When chemical pesticides must be used, materials should be selected that are the least harmful to parasites and predators. Insecticidal soaps, horticultural oils, and botanical extracts can often be integrated safely into a control program.

Many fungicides are toxic to beneficial organisms and should be avoided if possible. It is important to adopt practices that reduce disease pressure and the consequent need for fungicides. Examples of such practices include selecting disease-resistant varieties, purchasing disease-free seeds and plants, using well-drained soil, providing good air circulation, eradicating weeds, and assuring good sanitation.

INVENTORY MANAGEMENT

Proper management of pesticide inventories can greatly reduce the amount of waste generated as a result of the need to dispose of out-of-date products and clean up spills. Whenever possible, pesticide concentrates and formulations should be centrally stored and under the control of a limited number of personnel. Reducing the number of storage locations and personnel handling raw products reduces overall material handling and the associated chance of spills. Also, restricting access reduces the chance of unauthorized and untrained personnel mishandling pesticides. Larger firms may want to adopt a computerized inventory control system.

Inventory Management

- **Store centrally**
- **Limit number of personnel involved**
- **Adopt computerized inventory control**
- **Train personnel**
- **Limit quantities purchased**
- **Protect from exposure**
- **Eliminate spill hazards**

The quantity of pesticides stored on-site should be limited. Ordering small quantities of pesticide avoids many problems. First, the storage time of a pesticide may exceed its shelf life or a new, less toxic substitute may be developed, requiring management of excess product. Second, if a spill or fire occurs, less product will be involved, thus reducing the quantity of waste or emissions generated. Further, if a product is banned, any that is inventoried might become waste. A firm should avoid purchasing excess pesticides simply to obtain a discount, if possible. Pesticides should be purchased from a supplier that will accept timely return of full, unopened containers.

Pesticides should be stored in a covered area protected from moisture, sunlight, and temperature extremes. The storage area should be locked and ventilated and have secondary containment or positive drainage control to reduce the impact of a spill. Spill or damage hazards include storage on high shelves; exposure to activity, floor traffic, and machinery; and exposure to heat or sunlight. To avoid these hazards, product containers should be stored on sturdy pallets or shelves where they can be readily inspected for signs of damage or leakage on a regular basis.

PROPER MIXING

Properly mixing pesticides minimizes loss to the non-targeted environment as well as reduces worker exposure. Solid formulations for popular sprayable products, which must be dispersed in water before spraying, are sold as wettable powders, dry flowables, or water dispersible granules. While powders have significant dust-making potential, especially when conditions are windy, dry flowables and water-dispersible granules are dust free if they are well designed. However, granular products can get on pavement and in flower beds if they are improperly used. Microencapsulated liquid formulations of especially toxic active ingredients should be used to prevent unnecessary exposure (Hudson and Tarwater 1988).

Mixing only enough pesticide for the job at hand and using closed mixing systems and premeasured water-soluble packages, if available, will minimize waste from mixing and application processes (Marer 1988).

Proper Mixing

- **Use well-designed dry flowable and water-dispersible pesticides**
- **Use microencapsulated liquid formulations**
- **Mix only the amount required**
- **Use closed or in-line mixing systems**

Closed or in-line mixing systems reduce waste during spray application of pesticides (Noyes 1991). In an in-line mixing system, concentrated pesticide is drawn from a small, reusable reservoir and mixed with dilution water in the spray nozzle. Dilution water is supplied from a separate tank. Computerized in-line mixing systems provide controlled pesticide application. In-line mixing also eliminates container handling, rinsing, and disposal. Waste resulting from rinsing equipment is also reduced because the pesticide is not mixed in large-volume dilution water tanks. With computer controlled in-line mixing applicators, the amount of pesticide can be accurately metered.

PRODUCT SUBSTITUTION

Product substitution is an effective means of source reduction. Examples of product substitution applicable to the non-agricultural pesticides industry include

- Using physical, biological, or less hazardous chemical control techniques
- Using biodegradable herbicides instead of very persistent organochlorine herbicides
- Using insecticidal soaps instead of organophosphates or other broad spectrum insectides
- Using water-based formulations in place of organic solvent-based products

Product Substitution

- **Use physical, biological, or less hazardous chemical control techniques**
- **Use biodegradable herbicides**
- **Use insecticidal soaps**
- **Use water-based formulations**
- **Use dry granular or slow-release liquid pesticides**
- **Use horticultural controls**

- Using dry granular or slow-release liquid pesticides

- Using horticultural controls.

A variety of physical, biological, and chemical control techniques may be substituted for techniques that generate significant amounts of waste. (Bio-Integral Resource Center 1992, Fullick and Fullick 1991).

The choice of pest control measures may vary greatly by particular site and geographic location, variety of pest species, and acceptance of the customer or owner of the property to their use. The utilization of all these suggestions may be impractical, but trying to use even one of them may help decrease pollution. Some customers of those in the commercial application business are now specifically asking for alternative methods of pest control or pesticide-free programs, and the trend is expected to continue.

Physical Control

Physical control techniques include exclusion, trapping, vacuuming, cultivation, environment modification, and sanitation. Exclusion consists of using barriers (such as screens) to exclude pests. Trapping is a popular physical control method, and many different kinds of traps are available. Glue traps hung in trees or gardens capture numerous insects. Light traps and electrocutors attract insects with a fluorescent black light lamp and then either catch or kill them. This technique is only effective when used indoors (such as in a greenhouse) and in conjunction with good sanitation. Food traps are usually stocked with a liquid that lures and eventually drowns insects (e.g., a wide-mouth jar half-filled with a 10 percent molasses solution can be used to trap grasshoppers). An interesting variation is the use of trap crops, which are planted around crops to be harvested. Trap crops may also be used to attract beneficial insects to infested areas.

Several simple physical steps can be taken to make an environment less susceptible to a pest invasion. Tilling the soil regularly or spraying water on plant leaves will disturb the hiding places of pests. Pests can be suppressed in enclosed areas, such as greenhouses, by altering environmental conditions (e.g., temperature, light, and humidity). For example, bright lights discourage bats and low humidity discourages mold. Good sanitation eliminates factors necessary to a pest's survival.

Biological Control

In classical biological control programs, host-specific natural enemies that are not native to a geographical area are introduced to control exotic pests. Other forms of biological control augment and maintain a pest's natural enemies.

Biological controls can be effectively used in indoor or outdoor settings and on localized or widespread pest populations. To be effective, biocontrol agents should be released early in the season when pest populations are low. This allows natural enemies to overwhelm the incipient pest population before it can rise to damaging levels. Examples include releasing predatory mites in early summer when pest mite numbers begin to rise as temperatures increase, or releasing parasitic *Encarsia spp.* miniwasps to control whiteflies when the first preadult whitefly larvae are visible on the undersides of leaves.

Biological controls include plants that provide natural barriers to pests. Attracting birds that prey on insects to an area makes it more unsuitable to pests. Other natural enemies (such as herbivorous and carnivorous insect predators, as well as parasites) can stop a pest explosion and maintain pest populations at a tolerable level.

While not an option for all types of weeds, insects can be used instead of, or in conjunction with, herbicides to control weeds. For example, the seed-head weevil and seed-head fly larvae feed on the seeds of yellow star thistle, thereby destroying the pest plant's ability to reproduce (*Organic Gardening* 1989a). Another successful example is the use of weed-feeding insects against tansy ragwort. The combined attack of three such insects on the roots, leaves, and flowers of the ragwort reduced livestock poisoning in Oregon and resulted in an annual savings of $4 million (Poritz 1993). Dozens of other imported, host-specific, weed-feeding insects have resulted in dramatic declines of numerous exotic weeds worldwide. Carnivorous insect pest controllers include ladybugs for aphid control and spiders that attack planthoppers.

Host-specific herbivorous insects have been extensively imported to control pest invasions. However, the imported insect must come from a similar climate to ensure its survival. Introducing a carnivorous insect that kills the wrong insects or that mates with existing insects and produces a hybrid with unknown characteristics should be avoided. The vedalia beetle from Australia has been successfully introduced to eradicate cottony-cushion scale in California and the conservula caterpillar from South Africa has been introduced in Britain to destroy bracken (Fullick and Fullick 1991).

Bacterial insecticides are very effective in eradicating undesirable insect populations, and new uses for them are being developed. *Bacillus thuringiensis* (Bt) is the most common bacterium used and is a proven insecticide for over 15 species. Several subspecies of Bt exist, which facilitates pest-specific treatment of infected areas. Genetic engineering is increasingly important in increasing the virulence and range of bacteria for pest control. Genes from Bt have been introduced into selected vegetables (i.e., tomatoes). However, some insect resistance to these genetically engineered plants has been detected (Fullick and Fullick 1991).

Suppressing grasshopper infestations with *Nosema locustae* is an example of parasitic control of pests. This protozoan parasite infects the insects by direct exposure and is passed on to the next generation through the eggs of an infected adult (*Organic Gardening* 1989a).

Viral and fungal regulation of pests is being researched extensively (Carr et al. 1991). Viral pesticide field trial results are positive, but few products are available. Viral pesticides are expected to control gypsy moths, corn borers, tobacco budworms, and cabbage loopers without harm to animals or humans (*Organic Gardening* 1989b). A fungal pathogen that attacks and destroys the internal organs of locusts is being developed (Fullick and Fullick 1991). Rust fungus has been identified as a possible biological control for yellow star thistle. These techniques should be available within a few years.

Chemical Control

In addition to physical and biological controls, chemical methods such as placing salt-embedded plastic in a garden to kill slugs or spraying soapy water on plants to reduce aphid populations are often effective. Boric acid, if it remains dry, kills roaches, silverfish, and crickets and lasts longer than organophosphate sprays. Saturation of an infested area with the appropriate insect pheromone prevents males from finding females and mating (Holmes 1992).

Insect sex pheromones and other semiochemicals have been synthesized and formulated into monitoring and control products for many economically important insect pests. Monitoring traps, as discussed earlier, permit pest identification and population assessment. Recently, population control using pheromones has been demonstrated for several insects. The technique is known as mating disruption. Pheromone in a controlled-release formulation is broadcast or hand applied at rates high enough to out-compete calling females for males. As a result, no offspring are produced. In addition, beneficial insect populations are not adversely affected and outbreaks of secondary pests are prevented. Mating disruption products are available for a limited but growing list of pests (Holmes 1992).

Certain compounds are useful because of their sorptive properties. Silica aerogel used in confined areas such as wall voids and attics will dehydrate roaches, termites, fleas, and other insects. Although it exhibits low toxicity to animals and humans, silica aerogel may be toxic to fish and should not be used around lakes, streams, or ponds. Diatomaceous earth, which is a drying agent and has an abrasive property, can tear the cuticle and thus dehydrate insect pests (Olkowski and Olkowski 1989).

Using pesticides derived from plant extracts is an alternative to using traditional sprays. Extracts from the sabadilla lily and neem trees have been used against a variety of pests. Sabadilla powder is obtained by grinding the seeds from the lily and is usually mixed with diatomaceous earth before packaging. The poison paralyzes and kills pests a short time after contact and then deteriorates quickly in sunlight, leaving no active sabadilla residue on vegetation. Sabadilla can be used for cucumber beetles and harlequin bugs, but should not be used indiscriminately because it is toxic to honeybees, spiders, ladybugs, frogs, and fish (Pleasant 1991). Neem cake and neem oil, both from the seeds of the tree, are used as toxicants, growth-regulators, and antifeedants against over 25 species of pests. Neem oil may also protect against fungus and virus attacks, but more research is needed to support this claim. The extracts of other plants closely related to the neem tree (family Meliaceae) are being investigated for insecticidal properties (Olkowski 1989).

CONTAINER WASTE MINIMIZATION

Pesticide containers must comply with federal, state, and local regulations and should be designed to allow safe, rapid, and clean transfer of their contents.

Generally, pesticides are formulated and packaged by different groups within a company or by different companies. To improve containers, a change in perception is necessary from considering a container as simply a vessel to transport a pesticide to seeing the container as an important part of the pesticide delivery system. The relationship between the container and the pesticide is important in all stages of the pesticide/container life cycle, including container use (transportation, storage, transferring pesticide from the container, etc.), residue removal, and container disposal. To assist pesticide users, the pesticide industry must consider the pesticide formulation and its container as a unified system, which would require a significant change in production philosophy.

Efforts to improve pesticide container design should take into consideration

- Protecting the integrity of the pesticide product and the environment through which the container passes
- Transferring pesticide safely and easily from the container to the application equipment
- Minimizing the amount of unused pesticide residue remaining in the container after the pesticide has been transferred
- Minimizing the number of pesticide containers requiring disposal (Fitz 1991 and 1992).

Pesticide users can minimize waste by purchasing products in the container size needed for a particular period of time. Refillable, returnable containers minimize container waste because the user does not have to dispose of empty jugs, cans, or bags.

Water-soluble packaging, when available, also reduces waste. Water-soluble packages dissolve and become part of the application mixture, avoiding the need to clean containers and the need for measuring and mixing equipment. Certain pesticides marketed as wettable powders can now be purchased in water-soluble, polyvinyl alcohol film packets that are added directly to application equipment. Water-soluble packaging is also being investigated for liquid pesticides sold as emulsifiable liquid concentrates (Hudson and Tarwater 1988).

The National Agricultural Chemicals Association is pursuing several approaches to container waste minimization, including the development of refillable and water-soluble containers (Allison 1992). Tests are being conducted on the feasibility of granulating and recycling empty containers. The Agricultural Container Research Council (ACRC), a non-profit organization of U.S. agricultural chemical manufacturers, distributors, and dealers, has been formed to develop state-level container programs and to conduct research

Container Waste Minimization

- **Consider the pesticide formulation and its container as a unified system**
- **Purchase products in appropriate container sizes**
- **Purchase certain products in water-soluble packages**
- **Granulate and recycle containers**
- **Use container rinse water in application mixtures**

to find acceptable uses for empty plastic containers. A survey conducted in 1992 by the ACRC shows that more than half of the states have collection and recycling programs for plastic agricultural containers.

Container rinsing, which is required by many pesticide labels, is effective for source reduction if the rinse water is reused in application mixtures. Containers that are empty according to 40 CFR 261.7 are not regulated as hazardous waste.

EFFICIENT APPLICATION

The efficiency of applying pesticides can be improved by using the appropriate pesticide, properly timing applications, and more effectively controlling pesticide application. For example, spot treatment may be as effective as blanket application of a pesticide and is an effective way to reduce pesticide waste.

Generally, the application of pesticides should conform to manufacturer recommendations on the container or technical sheet, and applicators should have qualified formal training in pesticide usage. Infrequent or light application of the pesticide product may result in product ineffectiveness, or eventual pest resistance to the product. Too heavy or broad an application may needlessly and harmfully impact the environment. Deviations from manufacturer specifications must be based on reliable and competent technical sources and must be consistent with label directions. Examples would be the manufacturer's vendor or representative, a governmental agricultural experiment station or extension office, or a local university. These information sources may also have useful advice for minimizing generation of hazardous waste.

Efficient Application

- **Use the appropriate pesticide**
- **Follow manufacturer recommendations**
- **Practice spot treatment of pesticide**
- **Correctly sequence the application of pesticide**
- **Calibrate equipment regularly**
- **Implement controlled drop sprayer techniques such as rotary, air-assisted, and direct charge injection atomizers**
- **Avoid spraying by using ropewick, roller, or carpet applicators**
- **Select equipment of the most appropriate size**

Federal and state information sources on pollution prevention are listed in Appendix B. Other information sources for pollution prevention include industry associations, trade journals, trade shows, conferences, and workshops.

Application Timing and Sequencing

Timing the application of pesticides is important for controlling pests as well as protecting natural enemies and beneficial insects. By correctly sequencing the application of various pesticides, cleaning requirements can be significantly reduced. For example, applying one type of pesticide to all areas that require a particular treatment (e.g., insecticidal treatment), then applying another type (e.g., a herbicide) to other areas, eliminates the need to rinse equipment between applications. Another way to achieve the same effect is to have dedicated application systems (i.e., separate equipment for each type of pesticide), although this alternative may be too expensive for small businesses.

Because some pesticides are more effective at different stages in the life cycle of pests, proper timing of pesticide application is essential. If the pesticide is applied at the correct stage in the life cycle of a target pest, additional applications can be avoided. For example, by applying pre-emergents at the correct time, future applications of post-emergents may not be needed. In addition, because insects are frequently more sensitive at larval or immature stages of development, applying them at the proper time will increase the effectiveness of many insecticides. Treating boring insects before they penetrate deeply into the plant tissue is another example of proper timing.

Weather conditions also should be taken into account when planning pesticide applications so that the amount of pesticide applied to targeted plants or insects is maximized. Spray application efficiency will be compromised on windy days; therefore, applications should be rescheduled if windy conditions prevail. Depending on the type of pesticide, rain in small to moderate amounts can help or hinder application efficiency.

Application Technology

Improving application techniques, as well as using equipment of the appropriate size, increases the efficiency of pesticide application. Calibrating equipment more than once a year for granular and liquid pesticides is a simple and effective way to reduce waste.

Spraying. Many pesticides are applied as a dilute solution or suspension of pesticide concentrate in water. The diluted material is dispensed as a spray through a hydraulic nozzle. The standard hydraulic nozzle ejects a stream under pressure to form a liquid sheet at the nozzle tip. The sheet breaks up to form a spray of drops with a broad, randomly distributed drop size. For most pesticide applications, only a narrow size range of droplets is really effective in delivering the proper dose to the target. The actual drop size needed depends on the type of pesticide (for example, herbicide versus insecticide) and the target characteristics (for example, greenhouse versus lawn).

Hydraulic spraying is effective but inefficient. With the wide range of drop sizes formed, some of the drops will be in the required range; but drops not in the required range may not reach the target. The difficulty of calibration and maintenance in the field can further decrease the efficiency of hydraulic nozzles (Bals 1987).

Pesticide application equipment is now available to produce a spray with a reliably controlled drop size (Giles 1992). However, greater care is needed in selecting and operating sprayers to give the required drop size. The variety of sprayer types available allows selection of equipment specifically suited to the pesticide and target. The main types of controlled drop size sprayers are

- Rotary atomizers
- Air-assisted and electrostatic atomizers
- Direct charge injection atomizers.

Rotary spray atomizers improve drop size control and increase spray solution concentration, reducing application rates for many pesticides. Rotary atomizers produce drops by delivering spray solution to a rapidly rotating disk. The rotation speed of the disk and the solution feed rate determine the drop size. Rotary atomizers are available that allow field selection of the drop size. Because they can operate with a higher viscosity solution than nozzle sprayers, they are typically used with little or no carrier water.

Air-assisted atomizers combine pressurized air and pesticide streams in the nozzle to improve drop size control. The addition of a charging system in or just outside the nozzle imparts an electrostatic potential to each drop. The charged drops are attracted to a well-grounded target, repel each other, and, as a result, give more uniform coverage of the target.

Air-assisted and electrostatic atomizers produce the smaller drop sizes needed to allow an insecticide to reach the target pests, which typically concentrate on the underside of the leaf. An electrostatic charge improves the distribution of insecticide to the underside of the leaf. Further, the air-assisted electrostatic atomizers are particularly well suited for insecticide spraying on crops grown under cover where the crop can be well grounded and the drift of small drops can be controlled.

Direct electrostatic charging is an experimental technique applicable to fluids with low electrical conductivity. The method charge is directly injected into the flowing feed stream. A voltage is impressed on an electrode located inside the spray head, just prior to the exit orifice. The high voltage builds up electrons in the fluid. The charged fluid is ejected through the orifice and disperses into a plume of drops. Direct charge injection sprayers are potentially useful for applying oil-based pesticides (Simmons and Kelly 1987).

Wiping. Various mechanical wiping methods are available for applying herbicides (Larsen 1987). Some of the more commonly used types include

- Ropewick applicators
- Roller applicators
- Carpet applicators.

Ropewick applicators use the wicking action of ropes to carry herbicide from a reservoir and wipe it onto the target plant (e.g., grass). The ropes are usually connected to a reservoir, such as a section of pipe. Solution pressure and capillary action keep the rope saturated. Solution is transferred to plant leaves by contact with ropes as the reservoir pipe traverses the area to be treated. The ropewick system can selectively apply herbicide by adjusting the rope spacing or by adjusting the height of the ropes.

Roller applicators use a cylinder covered with an absorbing material, such as nylon carpet, to distribute herbicide. The absorber is wetted with solution and rotated. When the wet absorber on the surface of the cylinder contacts a plant, it wipes herbicide onto any leaf contacted. For best results, moisture sensing is needed to control wetting of the absorber, which minimizes dripping while maintaining sufficient herbicide on the roller. As with the ropewick applicators, coverage can be adjusted by changing the spacing and height of the rollers. Roller applicators are typically more expensive and more difficult to operate than ropewick applicators.

Carpet applicators use a sheet of absorbing material to distribute herbicide. A sheet of absorber, such as nylon carpet backed by an expanded metal grid, is hinged to hang vertically from a horizontal support. Herbicide solution sprays wet the back of the absorber. Runoff of herbicide is collected at the bottom of the absorber sheet, filtered, and recirculated to the sprays. The wetted absorber is moved over the area to be treated. As with the other systems, adjusting the spacing and height results in treatment area selectivity.

Selecting Appropriate Equipment Size. The size and type of application equipment should be selected to match the characteristics of the area to be treated. Most application equipment is suited only to a specific range of situations (Marer 1988). Equipment too large for the job is likely to release pesticide to the non-targeted environment, as well as increase the amount of rinsate generated during equipment cleanup.

GOOD HOUSEKEEPING PRACTICES

Implementing good housekeeping practices, in addition to training employees to reduce the potential for spills and improve application and cleanup practices, will reduce pesticide waste.

Good Housekeeping Practices

- **Train employees to follow good housekeeping practices**
- **Reduce the potential for spills**
- **Reduce the use of rinse water**
- **Reuse rinse water**
- **Clean and rinse equipment at the site**
- **Recycle containers**
- **Provide employees with reusable or semi-disposable protective clothing**

Rinse Water Minimization and Reuse

Water rinsing is the most common option for cleaning up equipment, containers, and spills; therefore, waste can be reduced by minimizing rinsing, where possible. For example, reusable containers eliminate the need for pesticide users to rinse empty containers, and good spill prevention, control procedures, and training reduce the need for post-job cleanup. Also, absorbent materials can be used to replace water rinsing, as appropriate, such as for absorbing spills. These pads or particulates will have to be properly disposed.

If water rinsing cannot be avoided, rinse volumes should be reduced by good water management practices, such as

- Treating water as a raw material with a real cost
- Setting water conservation goals
- Making water conservation a management priority
- Teaching employees how to use water efficiently
- Using high-pressure, low-volume cleaning systems
- Providing easy-to-use water shutoff valves at the final use point
- Using a broom or other dry method, rather than water spray.

Any rinse water generated should be collected on an impermeable area and reused, if possible. Rinse water can be reused in two ways:

- As a diluent in subsequent formulations of the same pesticide, in accordance with label directions
- As rinse water in future cleaning activities (Noyes 1992).

The first option is preferable because the excess rinse water is incorporated into a usable application mixture, eliminating the pesticide-bearing rinse water. Applicability of this option is restricted by the compatibility of the previous pesticide with that of the new formulation and the label directions, such as the allowable application sites and the maximum allowable rates. The second option is effective, although a liquid waste is still ultimately generated.

Cleaning and rinsing equipment at the site where it is used also reduces the amount of waste rinse water that must be managed. However, care must be taken to conduct these cleaning activities in areas that will not be adversely affected by the pesticide-containing rinse water. This practice must meet applicable regulatory guidelines.

Protective Clothing Waste Minimization and Reuse

Protective clothing is another waste that can be reused; however, the recycling process may generate hazardous waste.

Disposable clothing increases worker protection, but also significantly increases waste. Reusable cloth coveralls could eliminate this waste stream. However, the washwater from laundering reusable coveralls may be classified as a hazardous waste or require pretreatment prior to discharge, and cloth coveralls may not offer the same protection as disposable clothing.

A compromise alternative involves using semi-disposable protective clothing such as Sijal™ suits, which could be worn and cleaned for a limited time (e.g., one week) before needing disposal. This alternative would reduce the quantity of suits requiring disposal. Compliance with personal protective equipment directions on the label of protective clothing is always required.

Economics

If waste reduction options are not cost-effective, they may not be implemented unless mandated by regulations. The factors that influence the cost-effectiveness of a particular option include the initial capital cost and waste management cost. Many waste reduction options (such as inventory control to minimize obsolete chemicals) can be very cost-effective.

The high cost of complying with regulatory requirements or meeting environmental objectives may make waste reduction options attractive even for waste with otherwise low management costs. Some of the long-term costs of not minimizing waste may be significant, but difficult to predict. These include the cost of

- Long-term liability for land disposal
- Complying with new regulations limiting disposal
- Waste transportation, treatment, and disposal
- Increased insurance.

The economic aspects of various waste minimization options are discussed below. Many of these techniques require little if any capital expenditure and can reduce waste management costs significantly. Whether a given option is cost-effective depends on the quantity of waste generated, current waste management practices, and local disposal and treatment costs.

INTEGRATED PEST MANAGEMENT

If followed with care, IPM or PHC will result in the best, and least expensive, waste management program. Physical, biological, and cultural strategies are effective means of alleviating pest problems while minimizing risks to beneficial insects, animals, or people. They can be used separately or together depending on the magnitude of the problem. The use of existing pest management procedures and the practical application of current research should allow for more efficient, less expensive pest control while reducing the amount of chemicals introduced into the environment. Costs associated with implementing IPM and PHC strategies can be offset by reducing the use of pesticides, reducing the need for waste treatment, and reducing the liability associated with disposing of more hazardous pesticides.

INVENTORY MANAGEMENT

Capital costs associated with developing and implementing a good inventory management system depend on the current system. Possible costs include construction of an adequate product storage area, development of an inventory tracking system, and labor costs associated with centralizing existing stores of pesticides. If a usable storage area and efficient inventory tracking system are already in place, capital costs would be minimal.

A good inventory management system (including centralized storage, control, and distribution) will reduce obsolete inventory and product spills. Good inventory management can also reduce the cost of purchasing pesticide products.

PROPER MIXING AND PRODUCT SUBSTITUTION

Properly mixing and applying pesticides reduce costs because less pesticide is required. Three factors affect the cost-effectiveness of product substitution:

- Cost difference between the substitute and the original pesticide
- Capital and operating costs for application
- Waste management costs.

The cost difference for product substitution can be either positive or negative, but reducing the volume of pesticide applied can offset the higher cost of product substitution. Volume reduction techniques such as spot treatment or improved spray efficiency will help offset any increased unit cost or capital and operating costs. However, new equipment or more labor-intensive application techniques may be needed.

An indirect cost saving of proper mixing and product substitution is reduced liability related to worker exposure and waste disposal. Eliminating a waste stream removes the potential liability associated with disposal of the waste.

CONTAINER WASTE MINIMIZATION

The savings associated with rinsing empty containers can be substantial. Container cleaning is cost-effective if the rinse water is reused. If the rinse water cannot be reused, rinse water disposal must be considered. Container rinsing is not cost-effective if rinse water treatment increases overall waste management costs, although it still may be required by the label.

The cost of recycling containers can be significantly reduced if recycling programs are established. The Minnesota container recycling project found that the total cost of collecting and recycling was $3.69 per plastic pesticide container in 1991.

When permanent recycling programs are established and the number of containers collected is increased, the cost could be reduced by 50 percent (Hansen and Palmer 1991).

EFFICIENT APPLICATION

Costs to develop an efficient application program should be negligible except for very complex programs. Spot application and frequent calibration cost almost nothing and have the potential to significantly decrease pesticide costs. New, more efficient spraying equipment will be more expensive. The initial purchase and operating costs will be higher because of the need for training and because the equipment requires more demanding maintenance and calibration. Further, a piece of equipment that is specific for certain conditions may not be suitable for other conditions. As a result, more types of equipment may be needed to provide the full range of required application services and costs will be increased. The increased costs can be offset by reduced pesticide use, less dilution water hauling, and decreased rinse water disposal.

GOOD HOUSEKEEPING PRACTICES

Good housekeeping practices can be cost-effective. Costs associated with field cleaning equipment, containers, and clothing include the cost of obtaining and operating portable cleaning equipment. In many cases existing cleaning equipment (such as tanks and sprayers) can easily be modified for field use. Cost savings include reduced rinse water management costs.

Most rinse water minimization methods require a small investment. In general, rinse water is conserved by training employees to avoid spills, to clean up efficiently, and to consider water conservation while working. Therefore, although training costs will increase, wastewater conservation can reduce overall costs.

Reusing rinse water can be very economical. No significant costs are associated with this practice, and the savings are great. Waste streams amenable to recycling are rinse water from cleaning empty containers and protective clothing.

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SECTION 4
GUIDELINES FOR USING THE WASTE MINIMIZATION ASSESSMENT WORKSHEETS

The worksheets provided in this section are intended to assist the non-agricultural pesticides industry in systematically evaluating waste generating processes and in identifying waste minimization opportunities. These worksheets include only the assessment phase of the procedure described in the EPA *Waste Minimization Opportunity Assessment Manual* and the EPA *Facility Pollution Prevention Guide*. A comprehensive waste minimization assessment includes planning and organization, gathering background information, a feasibility study on specific waste minimization options, and an implementation phase. For a full description of waste minimization assessment procedures, refer to the *Facility Pollution Prevention Guide.*

Table 3 lists the worksheets that are provided in this section. After completing the worksheets, the assessment team should evaluate the applicable waste minimization options and develop an implementation plan.

Table 3. List of Waste Minimization Assessment Worksheets

Number	Title	Description
1.	Waste Sources	Form for listing specific waste types
2.	Waste Minimization: Integrated Pest Management	Questionnaire on pest management strategies
3.	Option Generation: Integrated Pest Management	Options for minimizing use of pesticides
4.	Waste Minimization: Pesticide Inventory	Questionnaire on managing, storing, and handling pesticides
5.	Option Generation: Pesticide Inventory	Options for better managing, storing, and handling pesticides
6.	Waste Minimization: Pesticide Mixing and Application	Questionnaire on mixing and applying pesticides
7.	Option Generation: Pesticide Mixing and Application	Options for improvements in mixing and applying pesticides
8.	Waste Minimization: Protective Clothing, Equipment, and Containers	Questionnaire on disposing protective clothing, equipment, cleaning waste, and empty containers
9.	Option Generation: Protective Clothing, Equipment, and Containers	Options for minimizing protective clothing, equipment cleaning, and container waste

Firm ____________	Waste Minimization Assessment	Prepared by ____________
		Checked by ____________
Date ____________	Proj. No. ____________	Sheet ___ of ___ Page ___ of ___

WORKSHEET
1A

WASTE SOURCES

Waste Source: Pesticide Inventory	Significance		
	Low	Medium	High
Excess Inventory			
Obsolete Materials			
Spills and Leaks			
Poor Housekeeping			
Inefficient Management			
Inappropriate Container Sizes			
Other			
Waste Source: Pesticide Mixing			
Highly Persistent Pesticides			
Improperly Diluted Pesticides			
Other			
Waste Source: Pesticide Application			
Poorly Timed Application			
Inappropriate Pesticide			
Inefficiently Dispensed Pesticide (i.e., poor spray or granule distribution pattern)			
Pesticide Dust and Droplets			
Other			

Firm ____________ Date ____________	Waste Minimization Assessment Proj. No. ____________	Prepared by ____________ Checked by ____________ Sheet ___ of ___ Page ___ of ___

WORKSHEET **1B**

WASTE SOURCES (Continued)

Waste Source: Pesticide Containers	Significance		
	Low	Medium	High
Rinsewater			
Empty Containers			
Container Cleaning Solvents			
Container Residue			
Other			
Waste Source: Equipment Cleaning and Protective Clothing			
Equipment Cleaning Rinse Water			
Cleaning Solvents			
Disposable Clothing			
Water from Laundering Reusable Clothing			
Other			

Firm ______________ Date ______________	Waste Minimization Assessment Proj. No. ______________	Prepared by ______________ Checked by ______________ Sheet ___ of ___ Page ___ of ___

WORKSHEET
2

WASTE MINIMIZATION: Integrated Pest Management

Have pests been identified?	☐ Yes ☐ No
Have their life cycles and ecological interactions been identified?	☐ Yes ☐ No
Have the boundaries of the area to be treated been determined?	☐ Yes ☐ No
Is a pest monitoring program in place?	☐ Yes ☐ No
Has the threshold level for implementation of a pest management program been reached?	☐ Yes ☐ No
Have treatment options been developed?	☐ Yes ☐ No
Has the pest management program been evaluated?	☐ Yes ☐ No

Firm ____________ Date ____________	Waste Minimization Assessment Proj. No. ____________	Prepared by ____________ Checked by ____________ Sheet ___ of ___ Page ___ of ___

WORKSHEET 3

OPTION GENERATION: Integrated Pest Management

Meeting Format (e.g., brainstorming, nominal group technique) ____________

Meeting Coordinator ____________

Meeting Participants ____________

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
A. Physical Control		
Use Barriers to Exclude Pests		
Trap Pests		
Till Soil		
Alter Environmental Conditions (temperature, light, humidity)		
Assure Good Sanitation		
Modify Habitat		
B. Biological Control		
Introduce Natural Enemies		
Maintain and Augment Natural Enemies		
C. Chemical Control		
Use Insect Pheromones		
Use Pesticides Based on Chemical Extracts from Plants (e.g., neem oil)		
Replace Toxic Chemicals with Less Toxic Chemicals		
Avoid Excessive Application of Chemicals		

Firm ____________ Date ____________	Waste Minimization Assessment Proj. No. ____________	Prepared by ____________ Checked by ____________ Sheet ___ of ___ Page ___ of ___

WORKSHEET

4A

WASTE MINIMIZATION: Pesticide Inventory

A. INVENTORY MANAGEMENT

How often are material inventories performed? ____________

How often are materials purchased? ____________

How is material usage controlled and tracked?

- Stockroom attendant ☐ Yes ☐ No
- Limited access ☐ Yes ☐ No
- Sign-out sheet ☐ Yes ☐ No
- Computerized ☐ Yes ☐ No
- Other ____________

Are pesticides used on a first-in, first-out basis? ☐ Yes ☐ No

How is obsolete material handled?

- Returned to supplier ☐ Yes ☐ No
- Managed as waste ☐ Yes ☐ No
- Tested for effectiveness ☐ Yes ☐ No
- Other ____________

For pesticides used infrequently or on a seasonal basis, are pesticides ordered on an as-needed basis? ☐ Yes ☐ No

B. STORAGE AND HANDLING

Storage or handling location? ____________

Distance from receiving area? ____________

Are new containers and drums inspected before being accepted? ☐ Yes ☐ No

Are storage areas routinely inspected for signs of spills, leaks, or hazards? ☐ Yes ☐ No

If yes, how often? ____________

Are materials stored in a manner that minimizes the chance of spills or damage? ☐ Yes ☐ No

Are hazardous materials

- Protected from weather? ☐ Yes ☐ No
- Stored in low traffic areas? ☐ Yes ☐ No
- Stored on stable shelves or pallets? ☐ Yes ☐ No
- Distance to mixing area? ____________

Firm ____________	Waste Minimization Assessment	Prepared by ____________
		Checked by ____________
Date ____________	Proj. No. ____________	Sheet ___ of ___ Page ___ of ___

WORKSHEET
4B

WASTE MINIMIZATION:
Pesticide Inventory
(Continued)

B. STORAGE AND HANDLING (Continued)

Does the storage area have secondary containment (e.g., berms) or drainage controls to prevent spills from entering the environment?	☐ Yes	☐ No
Is it impossible for material to be discharged from the facility before it is treated (e.g., through a drain in the storage area floor)?	☐ Yes	☐ No
Are hazardous materials stored separately from nonhazardous materials?	☐ Yes	☐ No
Are the storage areas kept clean and uncluttered?	☐ Yes	☐ No
Are hazardous materials properly stored, readily accessible, and easily visible for leak inspection and spill prevention?	☐ Yes	☐ No
Away from traffic?	☐ Yes	☐ No
Away from activity?	☐ Yes	☐ No
Leaks readily visible?	☐ Yes	☐ No
Container bottoms readily visible?	☐ Yes	☐ No
Minimal potential for puncture, tipping, dropping, other spill hazard?	☐ Yes	☐ No

Firm ____________	Waste Minimization Assessment	Prepared by ____________
Date ____________	Proj. No. ____________	Checked by ____________ Sheet ___ of ___ Page ___ of ___

WORKSHEET
5

OPTION GENERATION: Pesticide Inventory

Meeting Format (e.g., brainstorming, nominal group technique) ____________

Meeting Coordinator ____________

Meeting Participants ____________

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
A. Inventory Management		
Test Age-Dated Material (if expired) for Effectiveness		
Return Obsolete Material to Supplier		
Minimize Inventory		
Computerize Inventory		
Provide Formal Training		
Purchase Appropriate Sizes		
Limit Amounts Inventoried		
Minimize Number of Containers Being Disposed		
B. Storage and Handling		
Inspect New Containers		
Assure Proper Storage/Handling		
Reduce Traffic		
Reuse Spilled Material		
Provide Secondary Containment for Spills		
Use Cleanup Methods that Promote Recycling		
Segregate Waste		
Improve Accessibility		
Inspect Storage Areas		
Centralize Storage		
Limit Number of Personnel Handling Materials		
Restrict Access to Storage Areas		

Firm ______________	Waste Minimization Assessment	Prepared by ______________
		Checked by ______________
Date ______________	Proj. No. ______________	Sheet ___ of ___ Page ___ of ___

WORKSHEET
6A

WASTE MINIMIZATION: Pesticide Mixing and Application

A. PESTICIDE MIXING

Is product mixed in batches prior to use? ☐ Yes ☐ No

If no, what mixing method is used? ______________________________

Is the quantity of pesticide carefully matched to the amount needed for each application? ☐ Yes ☐ No

Are applications sequenced to reduce the amount of equipment cleaning required? ☐ Yes ☐ No

Is the area where pesticides are mixed close to the pesticide storage area? ☐ Yes ☐ No

Is the spill cleanup equipment readily accessible to the mixing area? ☐ Yes ☐ No

Is the mixing area located on an impermeable or sealed concrete surface? ☐ Yes ☐ No

If no, what type of surface? ______________________________

What type of waste water collection is provided in the mixing area?

Sump ☐	Ground Surface ☐	Single-Walled ☐	Portable ☐
Sump Pump ☐	Double-Walled ☐	Automatic ☐	
Dry Well ☐	Permanent ☐		
Storm Sewer ☐			

Are closed systems or inductor methods used? ☐ Yes ☐ No

Firm ____________ Date ____________	Waste Minimization Assessment Proj. No. ____________	Prepared by ____________ Checked by ____________ Sheet ___ of ___ Page ___ of ___

WORKSHEET
6B

WASTE MINIMIZATION: Pesticide Mixing and Application (Continued)

B. PRODUCT SUBSTITUTION

List products stored or in use that would require disposal as a hazardous waste. For each product, list the nonhazardous or less hazardous product(s) that can be substituted for it.

Product	Possible Substitute Product	Reason Substitute Not Used

C. PESTICIDE APPLICATION

How is the timing of pesticide application decided? ____________

____

What application technology is used? ____________

____

For spray applications, how is drop size determined? ____________

____

Is spot treatment possible? ____________

How often is equipment calibrated? ____________

What size equipment is available? ____________

____

Firm ____________	Waste Minimization Assessment	Prepared by ____________
Date ____________	Proj. No. ____________	Checked by ____________ Sheet ___ of ___ Page ___ of ___

WORKSHEET
7

OPTION GENERATION: Pesticide Mixing and Application

Meeting Format (e.g., brainstorming, nominal group technique) ____________

Meeting Coordinator ____________

Meeting Participants ____________

Suggested Waste Minimization Option	Currently Done Y/N?	Rationale/Remarks on Option
A. Pesticide Mixing		
Use In-Line Mixing Systems to Minimize Loss to Non-Targeted Environment		
Use Well-Designed Dry Flowable or Water-Dispersible Pesticides		
Use Microencapsulated Liquid Formulations		
B. Product Substitution		
Use Less Toxic or Biodegradable Pesticides		
Use Water-Based Formulations		
Substitute Physical, Biological, or Nonhazardous Chemical Control Techniques (see Worksheet 3)		
C. Pesticide Application		
Time Pesticide Application to Protect Natural Enemies and Beneficial Insects		
Apply Pesticides at Appropriate Stage of Pest's Life Cycle		
Use Controlled Drop Spraying Technologies		
Eliminate Spraying by Using Wiping Techniques		
Use Spot Treatment Rather Than Blanket Application		
Calibrate Equipment More Than Once a Year		

Firm ______ Date ______	Waste Minimization Assessment Proj. No. ______	Prepared by ______ Checked by ______ Sheet ___ of ___ Page ___ of ___

WORKSHEET
8

WASTE MINIMIZATION: Protective Clothing, Equipment, and Containers

A. PROTECTIVE CLOTHING

Could reusable or semi-disposable clothing be substituted for disposable clothing? ☐ Yes ☐ No

Number of employees who regularly use protective clothing: ___ Disposable ___Semi-Disposable ___Reusable

Would less protective clothing be required if fewer personnel had access to products requiring such clothing? ☐ Yes ☐ No

B. EQUIPMENT

Could the equipment cleaning waste that is not now recycled be reused?

Explain: ____

____

____

Is rinse water reused to dilute pesticide concentrate? ☐ Yes ☐ No

Are any of the following methods used to reduce the amount of rinse water generated from cleaning?

- Wiper blades ☐ Yes ☐ No
- High pressure nozzle ☐ Yes ☐ No
- Spray knife ☐ Yes ☐ No
- Other ____

If organic solvents are used for cleaning, could water or detergents be used instead? _________

Are employees trained in

Mixing?	☐	Spill control?	☐
Application?	☐	Equipment cleaning?	☐

C. CONTAINERS

List the type and quantity of containers disposed of each (circle one) month or year. Indicate whether the containers could be cleaned; if so, which cleaning solvent is required and could the rinsate be reused to dilute pesticide concentrate.

Container Type	Could Container be Cleaned? (Y/N)	Cleaning Solvent	Rinsate Reusable? (Y/N)

Firm ______	Waste Minimization Assessment	Prepared by ______
		Checked by ______
Date ______	Proj. No. ______	Sheet ___ of ___ Page ___ of ___

WORKSHEET
9

OPTION GENERATION: Protective Clothing, Equipment, and Containers

Meeting Format (e.g., brainstorming, nominal group technique) ______

Meeting Coordinator ______

Meeting Participants ______

Suggested Waste Minimization Option	Currently Done Y/N?	Rationale/Remarks on Option
A. Protective Clothing		
Use Reusable or Semi-Disposable Protective Clothing		
Clean Protective Clothing		
B. Equipment		
Minimize Use of Rinse Water		
Recycle Rinse Water		
Clean Equipment in the Field		
C. Containers		
Reuse Container Rinsate		
Purchase Products in the Correct Container Size		
Use Water-Soluble Packaging, Where Appropriate and Available		
Use Returnable Packaging, Where Appropriate and Available		

Appendix A
NON-AGRICULTURAL PESTICIDE INDUSTRY FIELD ASSESSMENTS: CASE STUDIES

In 1991, the California Department of Health Services (DHS)* published a waste minimization study (prepared by Tetra Tech, Inc. under contract to DHS), *Waste Audit Study: Non-Agricultural Pesticide Application Industry*, that included assessments of three non-agricultural pesticide waste generators. The objectives of the study were to

- Conduct assessments to determine waste minimization alternatives

- Prepare a model to be used by non-agricultural pesticide waste generators to assess their own waste minimization options.

Results of waste reduction assessments provide valuable information about the potential for incorporating waste reduction technologies into the non-agricultural pesticide industry. This appendix presents summaries of the results of the assessments performed by Tetra Tech at such operations. The summaries presented are largely unedited and should not be taken as recommendations of the USEPA; they are provided as examples only.

The California field assessments focus on waste management within the context of existing practices and equipment. They provide valuable insight into practical techniques to reduce waste with minimum departure from current practices. However, this guide to pollution prevention expands upon the concepts applied in the California field assessments to apply integrated pest management as the foundation of a total system approach to preventing pollution in the non-agricultural pesticide industry.

The original assessments may be obtained from

Mr. Benjamin Fries
California Department of Toxic Substances Control
P.O. Box 806
Sacramento, CA 95812-0806
(916) 322-3670

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* The Toxic Substances Control Program, Department of Health Services, has since been reorganized and is now the Department of Toxic Substances Control.

CASE STUDY A

Case Study A was an assessment of a large business and industrial park that served as a regional center for both interstate and international trade. A small maintenance crew employed by the park's management was responsible for applying herbicides to approximately 500 acres of the park.

Process Description

The California DHS found that all pest control activities were based at an operating station with a small warehouse to store herbicides, applicators, and other equipment. The crew used several herbicides including Roundup™, Surflan™, Oust™, and Karmex™. Surfactants were added to the herbicide formulations to aid mixing, and dyes were used as pattern indicators. All raw materials were stored in one of two locked rooms to which only the supervisor had access. Herbicides were purchased in the amount needed for the upcoming season. Individual containers were small, ranging in size from 2-gallon bottles to 30-gallon drums for liquids and 50-pound bags for dry herbicides. The park purchased approximately 2,200 pounds of herbicide annually.

The park applied herbicides using four 3-gallon back-mounted and hand-held sprayers, one 100-gallon truck-mounted sprayer, and one 200-gallon towed-spray boom. All herbicide was mixed in the sprayers themselves for the smaller units or in the supply tanks for the larger sprayers. For each application, the quantity of herbicide mixed was carefully matched to the area to be sprayed. Any herbicide left over was used in subsequent formulations. The sprayers were cleaned using a water and detergent solution. Cleaning frequency varied depending on the type of herbicide and the size of the sprayer. For example, the small 3-gallon sprayers were rinsed after every use, while the larger 100- and 200-gallon sprayers were only cleaned when switching from pre-emergent to post-emergent herbicides. Cleaning involved rinsing tanks with water or detergent several times and flushing the delivery hoses, booms, and nozzles. For the small units, rinse water from the first rinsing was used as makeup for subsequent formulations if the herbicides were compatible or sprayed on areas to be treated. Second and third rinsings were dumped on the ground. For the large units, the tanks were filled half full and the system was flushed for 15 to 20 minutes on areas to be treated. DHS recommended that the park verify that this is compatible with regulatory requirements and with responsible waste management practices.

Waste Generation and Management

The four primary waste streams generated by herbicide application activities included

- Used protective clothing
- Empty herbicide containers
- Obsolete and out-of-date herbicides
- Rinse water from applicator cleaning.

USED PROTECTIVE CLOTHING

Personnel applying herbicides routinely wore disposable protective clothing to limit their exposure. At the end of each shift, the used clothing was segregated based on the type of herbicide, bagged, and disposed of with the regular solid waste or taken to a Class III landfill, as appropriate.

EMPTY PESTICIDE CONTAINERS

Herbicides were delivered in two forms: liquid and wettable powder. Empty liquid containers were triple-rinsed and disposed of as a solid waste. The rinse water was used as makeup water for new application mixtures. Wettable powders were delivered in paper bags, which were disposed of as a solid waste when completely empty. Local health department officials routinely inspected the disposal of empty containers at the landfill.

OBSOLETE AND OUT-OF-DATE HERBICIDES

At the time of the assessment, the industrial park was arranging disposal of several obsolete or out-of-date herbicides. The previous supervisor had not maintained careful inventories and, as a result, had purchased many herbicides that were never used. Current operating practices precluded using many of these products because of their toxicity. The current purchasing and inventory system was designed to minimize this type of waste by ordering only what was needed for the season and making sure that old herbicides were used before new products. Approximately two drums (440 lbs) of out-of-date herbicide required disposal annually under the old management.

RINSE WATER FROM APPLICATOR CLEANING

Rinse water from cleaning sprayers and other equipment was either sprayed on vacant property or incorporated into new herbicide formulations. The rinse water contained water, residual herbicide formulation, and a biodegradable non-hazardous detergent.

Conclusions and Recommendations

With some minor exceptions, the California DHS found that waste management practices were effective in reducing the quantity of hazardous waste requiring disposal. Empty product containers, the largest single waste stream, were rinsed and the rinsate reused in new herbicide tank mixes. Little or nothing could be done to minimize the protective clothing waste stream. Disposal of obsolete and out-of-date herbicide inventory was apparently a one-time event caused by poor inventory control in the past. The new, much stricter control on the herbicide inventory will eliminate this waste stream in the future.

The California DHS recommended that spent rinse water from equipment cleaning be managed better. Currently some of the rinsewater from the smaller sprayers was reused in subsequent tank mixes. However, all of the spent rinse water from cleaning the larger sprayers was sprayed onto vacant fields within the operating station boundary. This rinse water was significantly more dilute than the original application-strength formulation, but repeated application of residual herbicides could lead to an accumulation of herbicides or herbicide breakdown products and could be a violation of the label.

The DHS recommended that the first rinse of all sprayers, including the 100- and 200-gallon units, be conducted with the minimum amount of water or detergent and that the rinse water be collected and reused. Rinse water should be incorporated into new tank mixes or used as rinse water in subsequent cleanings. Water from second and third rinsings should be used for future first rinsings. Sprayers should be rinsed only when necessary and not after every use. Rinse water should not be disposed to vacant land until compatibility with federal, state, and local regulatory requirements is verified.

CASE STUDY B

In Case Study B, a maintenance station located in the south San Francisco Bay Area maintained the rights-of-way, shoulders, and median strips for a regional road and highway system. Several regional crews reported directly to the station. Maintenance activities included weed and pest control.

The station consisted of a small office area, equipment warehouse, machine shop, and pesticide storage building on approximately two acres. Trucks, tankers, and other large equipment were parked in a large lot that was mostly paved. Public access was restricted by a six-foot-high perimeter fence.

Process Description

The California DHS found that the operation used several herbicides including Roundup™, Surflan™, Karmex™, Embark™, Diquat™, and Princep™, and Safer™, an insecticidal soap. All pesticide products were stored in a specially designed building. Access to the storage building was restricted to the supervisor and the senior application specialist.

Pesticides were purchased approximately three times per year to minimize the amount of product in storage at any one time. Typical quantities purchased were: Karmex™, 500 lb; Roundup™, 250 gal; Surflan™, 50 gal; and Diquat™, 15 gal. The largest individual containers were 50-pound bags for Karmex™ and 2.5-gallon containers for Roundup™. A complete inventory was taken monthly. Also, regional crews were given only a one-month "working stock" of pesticides.

The maintenance station used one 3,000-gallon tanker/boom truck, two 500-gallon boom trucks, one 300-gallon towable tank, and numerous backpack and hand-held units to apply pesticide. The 300-gallon towable tank was typically used as a nurse tank to fill the smaller units in the field. This practice greatly reduced the amount of mixing and pesticide handling required. One 500-gallon boom truck had been recently equipped with a computerized application system, which stored water and pesticide in separate tanks and metered the correct quantities to the nozzles, where pesticide and water were mixed prior to application. The programmable system took into account vehicle speed and wind velocity to apply the correct amount of pesticide and automatically shut down if necessary.

Pesticide was mixed in the application equipment. Only the quantity to be used on a given day was prepared. Any pesticide left at the end of the day was incorporated into the next day's batch. Equipment was cleaned in the field using fresh water stored on each of the vehicles. The larger tanks were cleaned at the station, with the rinse water used in subsequent formulations. Pesticide applications were sequenced to minimize the amount of cleaning required.

Waste Generation and Management

Used protective clothing and empty pesticide containers were the two major waste streams.

USED PROTECTIVE CLOTHING

Personnel applying pesticides routinely wore disposable protective clothing to limit their exposure. At the end of each shift, the used clothing was segregated based on the type of herbicide, bagged, and stored onsite in a fenced and locked area. Every four to six weeks, the used clothing was taken to a Class III landfill for disposal.

EMPTY PESTICIDE CONTAINERS

Pesticides were delivered to the main station in two forms: liquid and wettable powder. Empty liquid containers were triple-rinsed and disposed of as a solid waste. The rinse water was used as makeup water for new tank mixes. Wettable powders were delivered in plastic-lined paper bags, which were disposed of as a solid waste when completely empty. Local health department officials routinely inspected the disposal of empty pesticide containers at the landfill.

Conclusions and Recommendations

The DHS concluded that the maintenance station had effectively implemented several waste minimization practices, practically eliminated the generation of hazardous waste, and reduced the quantity of solid waste generated. Waste minimization efforts included inventory control, product substitution, application sequencing, and improved application technology. Because the operation generated little, if any, hazardous waste, the DHS recommended that future waste minimization efforts should focus on product substitution to reduce the impact of pesticide application activities on the environment. The maintenance station could also buy pesticide in refillable containers (especially Karmex™ and Roundup™).

Continuing to upgrade the efficiency of the pesticide application equipment was also recommended. When cleaning parts in the field, the maintenance station should collect the spent rinse water in the tank from which the pesticide was drained. When the tank is subsequently cleaned at the station, that rinse water should be used as the first rinse, followed by subsequent cleaning with fresh water. The spent rinse water might be usable for mixing.

CASE STUDY C

Case Study C was the assessment of a large park system that covers several thousand acres of land. The system included golf courses, a botanical garden, commercial farms, and rangelands. As part of routine pest management, 35 pest applicators were employed by the park system. The park system used an integrated pest management program to determine pest control strategies.

Process Description

The pest control program involved treatment strategies for each pest on a systemwide basis. Pest status and control strategies were monitored and recorded, allowing the park system to evaluate the effectiveness of control strategies and to monitor pesticide application levels necessary to attain required results.

Pest control measures included some that did not require pesticide use, including habitat modification, physical control, plant selection, and biological control measures. Chemical control measures were used only as a last resort.

The park system coordinated pest control activities through pest management programs. Pesticides and application equipment were stored at the headquarters. Access to the storage area was restricted. The storage area was weatherproof, ventilated, and periodically inspected for physical damage. An inventory program ensured that only authorized amounts of pesticides were removed from the premises.

The park system required completion of pest management checklists and preparation of pesticide use reports prior to using pesticides. These documents were used to assess the effectiveness of pest management action and monitor pesticide use. The pesticides used at the park system were reviewed by park management. Only certified or licensed firms were allowed to use approved pesticides within the park system. Authorization was required prior to the use of pesticides on the property. The park system used a variety of algicides, fungicides, herbicides, and insecticides. Most of the pesticides used were Category III and IV compounds, including Roundup™, Surflan™, Karmex™, and Rodeo™. Category I and Category II compounds were used infrequently and applied by qualified firms. Surfactants and dye indicators were mixed with some of the herbicides. The park system had discontinued the use of most Category I pesticides. Obsolete pesticides were disposed of by a qualified disposal contractor. Pesticide purchases occurred in the quantities necessary to fulfill the needs of a pest management program.

The park system used a variety of application equipment, including back-mounted and hand-held sprayers and truck-mounted sprayers. All pesticides were mixed on-site. Applicators were cleaned with a water and detergent solution. Cleaning occurred on-site unless a compatible pesticide was prepared in the applicator. Most of the applicators were dedicated to the use of a particular pesticide, which reduced the frequency of cleaning.

Waste Generation and Management

The DHS found that four primary waste streams were generated by pesticide application activities:

- Used protective clothing
- Empty pesticide containers
- Rinse water from applicator cleaning
- Spill cleanup material.

Protective clothing was bagged and disposed of with regular waste. Empty pesticide containers were triple-rinsed, punctured, and disposed of in a Class III facility. Rinse water was sprayed on vegetation or incorporated into new pesticide formulations. Spill cleanup material was stored in containers until arrangements were made for proper disposal. County agricultural officials routinely inspected storage facilities and monitored disposal of empty pesticide containers.

Conclusions and Recommendations

The DHS concluded that the pest management practices were very effective in reducing the quantity of hazardous waste requiring disposal. The park system's pest management policies reduced the amount of waste generated. Waste was minimal and limited to used protective clothing, empty pesticide containers, rinse water from applicator cleaning, and spill cleanup material. The DHS recommended focusing on increased efficiency of pesticide application and pesticide use.

Appendix B
WHERE TO GET HELP: FURTHER INFORMATION ON POLLUTION PREVENTION

Additional information on source reduction, reuse and recycling approaches to pollution prevention is available in EPA reports listed in this section, and through state programs and regional EPA offices (listed below) that offer technical and/or financial assistance in the areas of pollution prevention and treatment.

Waste exchanges have been established in some areas of the United States to put waste generators in contact with potential users of the waste. Twenty-four exchanges operating in the United States and Canada are listed. Finally, relevant industry associations are listed.

U.S. EPA Reports on Waste Minimization

Facility Pollution Prevention Guide. EPA/600/R-92/088.*

Waste Minimization Opportunity Assessment Manual. EPA/625/7-88/003.*

Waste Minimization Audit Report: Case Studies of Corrosive and Heavy Metal Waste Minimization Audit at a Specialty Steel Manufacturing Complex. Executive Summary. EPA No. PB88-107180.**

Waste Minimization Audit Report: Case Studies of Minimization of Solvent Waste for Parts Cleaning and from Electronic Capacitor Manufacturing Operation. Executive Summary. EPA NO. PB87-227013.**

Waste Minimization Audit Report: Case Studies of Minimization of Cyanide Wastes from Electroplating Operations. Executive Summary. EPA No. PB87-229662.**

Report to Congress: Waste Minimization, Vols. I and II. EPA/530-SW-86-033 and -034 (Washington, D.C.: U.S. EPA, 1986).***

Waste Minimization—Issues and Options, Vols. I-III. EPA/530-SW-86-041 through -043. (Washington, D.C.: U.S. EPA, 1986.)***

The Guides to Pollution Prevention manuals* describe waste minimization options for specific industries. This is a continuing series which currently includes the following titles:

Guides to Pollution Prevention: Paint Manufacturing Industry. EPA/625/7-90/005.

Guides to Pollution Prevention: The Pesticide Formulating Industry. EPA/625/7-90/004.

Guides to Pollution Prevention: The Commercial Printing Industry. EPA/625/7-90/008.

Guides to Pollution Prevention: The Fabricated Metal Industry. EPA/625/7-90/006.

Guides to Pollution Prevention for Selected Hospital Waste Streams. EPA/625/7-90/009.

Guides to Pollution Prevention: Research and Educational Institutions. EPA/625/7-90/010.

Guides to Pollution Prevention: The Printed Circuit Board Manufacturing Industry. EPA/625/7-90/007.

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* Available from EPA CERI Publications Unit (513) 569-7562, 26 West Martin Luther King Drive, Cincinnati, OH, 45268.

** Executive Summary available from EPA, CERI Publications Unit, (513) 569-7562, 26 West Martin Luther King Drive, Cincinnati, OH, 45268; full report available from the National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, VA, 22161.

*** Available from the National Technical Information Service as a five-volume set, NTIS No. PB-87-114-328.

Guides to Pollution Prevention: The Pharmaceutical Industry. EPA/625/7-91/017.

Guides to Pollution Prevention: The Photoprocessing Industry. EPA/625/7-91/012.

Guides to Pollution Prevention: The Fiberglass Reinforced and Composite Plastic Industry. EPA/628/7-91/014.

Guides to Pollution Prevention: The Automotive Repair Industry. EPA/625/7-91/013.

Guides to Pollution Prevention: The Automotive Refinishing Industry. EPA/625/7-91/016.

Guides to Pollution Prevention: The Marine Maintenance and Repair Industry. EPA/625/7-91/015.

Guides to Pollution Prevention: The Metal Casting and Heat Treating Industry. EPA/625/R-92/009.

Guides to Pollution Prevention: Mechanical Equipment Repair Shops. EPA/625/R-92/008.

Guides to Pollution Prevention: The Metal Finishing Industry. EPA/625/R-92/011.

U.S. EPA Pollution Prevention Information Clearinghouse (PPIC): *Electronic Information Exchange System (EIES)—User Guide, Version 1.1.* EPA/600/9-89/086.

Waste Reduction Technical/ Financial Assistance Programs

The EPA Pollution Prevention Information Clearinghouse (PPIC) was established to encourage waste reduction through technology transfer, education, and public awareness. PPIC collects and disseminates technical and other information about pollution prevention through a telephone hotline and an electronic information exchange network. Indexed bibliographies and abstracts of reports, publications, and case studies about pollution prevention are available. PPIC also lists a calendar of pertinent conferences and seminars, information about activities abroad, and a directory of waste exchanges. Its Pollution Prevention Information Exchange System (PPIES) can be accessed electronically 24 hours a day without fees.

For more information contact:

PPIES Technical Assistance
Science Applications International Corp.
8400 Westpark Drive
McLean, VA 22102
(703) 821-4800

or

U.S. Environmental Protection Agency
401 M Street S.W.
Washington, D.C. 20460

Myles E. Morse
Office of Environmental Engineering and Technology Demonstration
(202) 260-5748

Priscilla Flattery
Pollution Prevention Office
(202) 260-8383

The EPA's Office of Solid Waste and Emergency Response has a telephone call-in service to answer questions regarding RCRA and Superfund (CERCLA). The telephone numbers are:

(800) 242-9346 (outside the District of Columbia)

(202) 382-3000 (in the District of Columbia)

The following programs offer technical and/or financial assistance for waste minimization and treatment.

Alabama

Hazardous Material Management and Resource Recovery Program
University of Alabama
P.O. Box 6373
Tuscaloosa, AL 35487-6373
(205) 348-8401

Department of Environmental Management
1751 Federal Drive
Montgomery, AL 36130
(205) 271-7914

Alaska
Alaska Health Project
Waste Reduction Assistance Program
431 West Seventh Avenue, Suite 101
Anchorage, AK 99501
(907) 276-2864

Arizona
Arizona Department of Economic Planning and Development
1645 West Jefferson Street
Phoenix, AZ 85007
(602) 255-5705

Arkansas
Arkansas Industrial Development Commission
One State Capitol Mall
Little Rock, AR 72201
(501) 371-1370

California
Pollution Prevention, Public and Regulatory Assistance Program
Department of Toxic Substances Control
California State Department of Health Services
P.O. Box 806
Sacramento, CA 95812-0806
(916) 322-3670

Pollution Prevention Program
San Diego County Department of Health Services
Hazardous Materials Management Division
P.O. Box 85261
San Diego, CA 92186-5261
(619) 338-2215

Colorado
Division of Commerce and Development Commission
500 State Centennial Building
Denver, CO 80203
(303) 866-2205

Connecticut
Connecticut Hazardous Waste Management Service
Suite 360
900 Asylum Avenue
Hartford, CT 06105
(203) 244-2007

Connecticut Department of Economic Development
210 Washington Street
Hartford, CT 06106
(203) 566-7196

Delaware
Delaware Department of Community Affairs & Economic Development
630 State College Road
Dover, DE 19901
(302) 736-4201

District of Columbia
U.S. Department of Energy
Conservation and Renewable Energy
Office of Industrial Technologies
Office of Waste Reduction, Waste Material Management Division
Bruce Cranford CE-222
Washington, DC 20585
(202) 586-9496

Pollution Control Financing Staff
Small Business Administration
1441 "L" Street, N.W., Room 808
Washington, DC 20416
(202) 653-2548

Florida
Waste Reduction Assistance Program
Florida Department of Environmental Regulation
2600 Blair Stone Road
Tallahassee, FL 32399-2400
(904) 488-0300

Georgia
Hazardous Waste Technical Assistance Program
Georgia Institute of Technology
Georgia Technical Research Institute
Environmental Health and Safety Division
O'Keefe Building, Room 027
Atlanta, GA 30332
(404) 894-3806

Environmental Protection Division
Georgia Department of Natural Resources
205 Butler Street, S.E., Suite 1154
Atlanta, GA 30334
(404) 656-2833

Guam
Solid and Hazardous Waste Management Program
Guam Environmental Protection Agency
IT&E Harmon Plaza, Complex Unit D-107
130 Rojas Street
Harmon, Guam 96911
(671) 646-8863-5

Hawaii
Department of Planning & Economic Development
Financial Management and Assistance Branch
P.O. Box 2359
Honolulu, HI 96813
(808) 548-4617

Idaho
IDHW-DEQ
Hazardous Materials Bureau
450 West State Street, 3rd Floor
Boise, ID 83720
(208) 334-5879

Illinois
Illinois EPA
Office of Pollution Prevention
2200 Churchill Road
P.O. Box 19276
Springfield, IL 62794-9276
(217) 782-8700

Hazardous Waste Research and Information Center
Illinois Department of Energy and Natural Resources
One East Hazelwood Drive
Champaign, IL 61820
(217) 333-8940

Illinois Waste Elimination Research Center
Pritzker Department of Environmental Engineering
Alumni Memorial Hall, Room 103
Illinois Institute of Technology
3201 South Dearborn
Chicago, IL 60616
(312) 567-3535

Indiana
Environmental Management and Education Program
School of Civil Engineering
Purdue University
2129 Civil Engineering Building
West Lafayette, IN 47907
(317) 494-5036

Indiana Department of Environmental Management
Office of Technical Assistance
P.O. Box 6015
105 South Meridian Street
Indianapolis, IN 46206-6015
(317) 232-8172

Iowa
Center for Industrial Research and Service
Iowa State University
Suite 500, Building 1
2501 North Loop Drive
Ames, IA 50010-8286
(515) 294-3420

Iowa Department of Natural Resources
Air Quality and Solid Waste Protection Bureau
Wallace State Office Building
900 East Grand Avenue
Des Moines, IA 50319-0034
(515) 281-8690

Waste Management Authority
Iowa Department of Natural Resources
Henry A. Wallace Building
900 East Grand
Des Moines, IA 50319
(515) 281-8489

Iowa Waste Reduction Center
University of Northern Iowa
75 Biology Research Complex
Cedar Falls, IA 50614
(319) 273-2079

Kansas
Bureau of Waste Management
Department of Health and Environment
Forbes Field, Building 730
Topeka, KS 66620
(913) 269-1607

Kentucky
Division of Waste Management
Natural Resources and Environmental Protection Cabinet
18 Reilly Road
Frankfort, KY 40601
(502) 564-6716

Kentucky Partners
Room 312 Ernst Hall
University of Louisville
Speed Scientific School
Louisville, KY 40292
(502) 588-7260

Louisiana
Department of Environmental Quality
Office of Solid and Hazardous Waste
P.O. Box 44307
Baton Rouge, LA 70804
(504) 342-1354

Maine
State Planning Office
184 State Street
Augusta, ME 04333
(207) 289-3261

Maryland
Maryland Hazardous Waste Facilities Siting Board
60 West Street, Suite 200 A
Annapolis, MD 21401
(301) 974-3432

Massachusetts
Office of Technical Assistance
Executive Office of Environmental Affairs
100 Cambridge Street, Room 1904
Boston, MA 02202
(617) 727-3260

Source Reduction Program
Massachusetts Department of Environmental Quality Engineering
1 Winter Street
Boston, MA 02108
(617) 292-5982

Michigan
Resource Recovery Section
Department of Natural Resources
P.O. Box 30028
Lansing, MI 48909
(517) 373-0540

Minnesota
Minnesota Pollution Control Agency
Solid and Hazardous Waste Division
520 Lafayette Road
St. Paul, MN 55155
(612) 296-6300

Minnesota Technical Assistance Program
1313 5th Street, S.E., Suite 207
Minneapolis, MN 55414
(612) 627-4646
(800) 247-0015 (in Minnesota)

Mississippi
Waste Reduction & Minimization Program
Bureau of Pollution Control
Department of Environmental Quality
P.O. Box 10385
Jackson, MS 39289-0385
(601) 961-5190

Missouri
State Environmental Improvement and Energy Resources Agency
P.O. Box 744
Jefferson City, MO 65102
(314) 751-4919

Waste Management Program
Missouri Department of Natural Resources
Jefferson Building, 13th Floor
P.O. Box 176
Jefferson City, MO 65102
(314) 751-3176

Nebraska
Land Quality Division
Nebraska Department of Environmental Control
Box 98922
State House Station
Lincoln, NE 68509-8922
(402) 471-2186

Hazardous Waste Section
Nebraska Department of Environmental Control
P.O. Box 98922
Lincoln, NE 68509-8922
(402) 471-2186

New Hampshire
New Hampshire Pollution Prevention Program
6 Hazen Drive
Concord, NH 03301-6509
(603) 271-2901

New Jersey
New Jersey Hazardous Waste Facilities Siting Commission
Room 514
28 West State Street
Trenton, NJ 08625
(609) 292-1459
(609) 292-1026

Hazardous Waste Advisement Program
Bureau of Regulation and Classification
New Jersey Department of Environmental Protection
401 East State Street
Trenton, NJ 08625
(609) 292-8341

Risk Reduction Unit
Office of Science and Research
New Jersey Department of Environmental Protection
401 East State Street
Trenton, NJ 08625
(609) 292-8341

New Mexico
Economic Development Department
Bataan Memorial Building
State Capitol Complex
Santa Fe, NM 87503
(505) 827-6207

New York
New York Environmental Facilities Corporation
50 Wolf Road
Albany, NY 12205
(518) 457-4222

North Carolina
Pollution Prevention Pays Program
Department of Natural Resources and Community Development
P.O. Box 27687
512 North Salisbury Street
Raleigh, NC 27611-7687
(919) 733-7015

Governor's Waste Management Board
P.O. Box 27687
325 North Salisbury Street
Raleigh, NC 27611-7687
(919) 733-9020

Technical Assistance Unit
Solid and Hazardous Waste Management Branch
North Carolina Department of Human Resources
P.O. Box 2091
306 North Wilmington Street
Raleigh, NC 27602
(919) 733-2178

North Dakota
North Dakota Economic Development Commission
Liberty Memorial Building
State Capitol Grounds
Bismarck, ND 58505
(701) 224-2810

Ohio
Division of Hazardous Waste Management
Division of Solid and Infectious Waste Management
Ohio Environmental Protection Agency
P.O. Box 0149
1800 Watermark Drive
Columbus, OH 43266-0149
(614) 644-2917

Oklahoma
Industrial Waste Elimination Program
Oklahoma State Department of Health
P.O. Box 53551
Oklahoma City, OK 73152
(405) 271-7353

Oregon
Oregon Hazardous Waste Reduction Program
Department of Environmental Quality
811 Southwest Sixth Avenue
Portland, OR 97204
(503) 229-5913
(800) 452-4011 (in Oregon)

Pennsylvania
Pennsylvania Technical Assistance Program
501 F. Orvis Keller Building
University Park, PA 16802
(814) 865-0427

Center of Hazardous Material Research
Subsidiary of the University of Pittsburgh Trust
320 William Pitt Way
Pittsburgh, PA 15238
(412) 826-5320
(800) 334-2467

Puerto Rico
Government of Puerto Rico
Economic Development Administration
Box 2350
San Juan, PR 00936
(809) 758-4747

Rhode Island
Hazardous Waste Reduction Section
Office of Environmental Management
83 Park Street
Providence, RI 02903
(401) 277-3434
(800) 253-2674 (in Rhode Island)

South Carolina
Center for Waste Minimization
Department of Health and Environmental Control
2600 Bull Street
Columbia, SC 29201
(803) 734-4715

South Dakota
Department of State Development
P.O. Box 6000
Pierre, SD 57501
(800) 843-8000

Tennessee
Center for Industrial Services
University of Tennessee
Building #401
226 Capitol Boulevard
Nashville, TN 37219-1804
(615) 242-2456

Bureau of Environment
Tennessee Department of Health and Environment
150 9th Avenue North
Nashville, TN 37219-5404
(615) 741-3657

Tennessee Hazardous Waste Minimization Program
Tennessee Department of Economic and Community Development
Division of Existing Industry Services
7th Floor, 320 6th Avenue, North
Nashville, TN 37219
(615) 741-1888

Texas
Texas Economic Development Authority
410 East Fifth Street
Austin, TX 78701
(512) 472-5059

Utah
Utah Division of Economic Development
6150 State Office Building
Salt Lake City, UT 84114
(801) 533-5325

Vermont
Economic Development Department
Pavilion Office Building
Montpelier, VT 05602
(802) 828-3221

Virginia
Office of Policy and Planning
Virginia Department of Waste Management
11th Floor, Monroe Building
101 North 14th Street
Richmond, VA 23219
(804) 225-2667

Washington
Hazardous Waste Section
Mail Stop PV-11
Washington Department of Ecology
Olympia, WA 98504-8711
(206) 459-6322

West Virginia
Governor's Office of Economics and Community Development
Building G, Room B-517
Capitol Complex
Charleston, WV 25305
(304) 348-2234

Wisconsin
Bureau of Solid Waste Management
Wisconsin Department of Natural Resources
P.O. Box 7921
101 South Webster Street
Madison, WI 53707
(608) 267-3763

Wyoming
Solid Waste Management Program
Wyoming Department of Environmental Quality
Herschler Building, 4th Floor, West Wing
122 West 25th Street
Cheyenne, WY 82002
(307) 777-7752

Waste Exchanges

ACS California Section
Wayne Phillips
Custom Lab Supply
2127 Research Drive
Livermore, CA 94550
(501) 633-1329

Alberta Waste Materials Exchange
Mr. Jim Renick
303A Provincial Building
4920 51st Street
Red Deer, Alberta
CANADA T4N 6KB
(403) 340-7980

B.A.R.T.E.R. Waste Exchange
Mr. Jamie Anderson
MPIRG
2512 Delaware Street SE
Minneapolis, MN 55414
(612) 627-6811

British Columbia Waste Exchange
Mr. Robert Smith
1525 West 8th Avenue
Vancouver, B.C.
CANADA V6J 1T5
(604) 731-7222 - General Information
(604) 732-9253 - Recycler Data Base

California Materials Exchange (CALMAX)
Ms. Joyce Mason
Local Government Commission
909 12th St., Suite 205
Sacramento, CA 95814
(916) 448-1198
FAX: (916) 448-8246

California Waste Exchange
Ms. Claudia Moore
Department of Toxic Substances Control
P.O. Box 806
Sacramento, CA 95812-0806
(916) 322-4742

Canadian Chemical Exchange*
Mr. Philippe LaRoche
P.O. Box 1135
Ste-Adele, Quebec
CANADA J0R 1L0
(514) 229-6511

Canadian Waste Materials Exchange
ORTECH International
Dr. Robert Laughlin
2395 Speakman Drive
Mississauga, Ontario
CANADA L5K 1B3
(416) 822-4111 (Ext. 265)
FAX: (416) 823-1446

Indiana Waste Exchange
Ms. Susan Scrogham
P.O. Box 1220
Indianapolis, IN 46206
(317) 634-2142

Industrial Materials Exchange
Mr. Bill Lawrence
172 20th Avenue
Seattle, WA 98122
(206) 296-4633
FAX: (206) 296-0188

Industrial Materials Exchange Service
Ms. Diane Shockey
P.O. Box 19276
Springfield, IL 62794-9276
(217) 782-0450
FAX: (217) 524-4193

* For-Profit Waste Information Exchange

Iowa Waste Reduction Center
(By-product Waste Search Service)
Ms. Susan Salterberg
75 BRC
University of Northern Iowa
Cedar Falls, IA 50614-0185
(800) 422-3109
(319) 273-2079
FAX: (319) 273-2893

Louisiana/Gulf Coast Waste Exchange
Ms. Rita Czek
1419 CEBA
Baton Rouge, LA 70803
(504) 388-8650
FAX: (504) 388-4945

Manitoba Waste Exchange
Mr. James Ferguson
c/o Biomass Energy Institute, Inc.
1329 Niakwa Road
Winnipeg, Manitoba
CANADA R2J 3T4
(204) 257-3891

Montana Industrial Waste Exchange
Mr. Don Ingles
Montana Chamber of Commerce
P.O. Box 1730
Helena, MT 59624
(406) 442-2405

Northeast Industrial Waste Exchange, Inc.
Mr. Lewis Cutler
90 Presidential Plaza, Suite 122
Syracuse, NY 13202
(315) 422-6572
FAX: (315) 422-9051

Ontario Waste Exchange
ORTECH International
Ms. Linda Varangu
2395 Speakman Drive
Mississauga, Ontario
CANADA L5K 1B3
(416) 822-4111 (Ext. 512)
FAX: (416) 823-1446

Pacific Materials Exchange
Mr. Bob Smee
South 3707 Godfrey Boulevard
Spokane, WA 99204
(509) 623-4244

Peel Regional Recycling Assistance
(Publishes Directory of Local Recyclers)
Mr. Glen Milbury
Regional Municipality of Peel
10 Peel Center Drive
Brampton, Ontario
CANADA L6T 4B9
(416) 791-9400

RENEW
Ms. Hope Castillo
Texas Water Commission
P.O. Box 13087
Austin, TX 78711-3087
(512) 463-7773
FAX: (512) 463-8317

Southeast Waste Exchange
Ms. Maxie L. May
Urban Institute
UNCC Station
Charlotte, NC 28223
(704) 547-2307

Southern Waste Information Exchange
Mr. Eugene B. Jones
P.O. Box 960
Tallahassee, FL 32302
(800) 441-SWIX (7949)
(904) 644-5516
FAX: (904) 574-6704

Wastelink, Division of Tencon, Inc.
Ms. Mary E. Malotke
140 Wooster Pike
Milford, OH 45150
(513) 248-0012
FAX: (513) 248-1094

U.S. EPA Regional Offices

Region 1 (VT, NH, ME, MA, CT, RI)
John F. Kennedy Federal Building
Boston, MA 02203
(617) 565-3715

Region 2 (NY, NJ, PR, VI)
26 Federal Plaza
New York, NY 10278
(212) 264-2525

Region 3 (PA, DE, MD, WV, VA, DC)
841 Chestnut Street
Philadelphia, PA 19107
(215) 597-9800

Region 4 (KY, TN, NC, SC, GA, FL, AL, MS)
345 Courtland Street, N.E.
Atlanta, GA 30365
(404) 347-4727

Region 5 (WI, MN, MI, IL, IN, OH)
230 South Dearborn Street
Chicago, IL 60604
(312) 353-2000

Region 6 (NM, OK, AR, LA, TX)
1445 Ross Avenue
Dallas, TX 75202
(214) 655-6444

Region 7 (NE, KS, MO, IA)
756 Minnesota Avenue
Kansas City, KS 66101
(913) 236-2800

Region 8 (MT, ND, SD, WY, UT, CO)
999 18th Street
Denver, CO 80202-2405
(303) 293-1603

Region 9 (CA, NV, AZ, HI, GU)
75 Hawthorne Street
San Francisco, CA 94105
(415) 744-1305

Region 10 (AK, WA, OR, ID)
1200 Sixth Avenue
Seattle, WA 98101
(206) 442-5810

Industry and Trade Associations and Other Sources of Information

Agricultural Container Research Council
Hayley-Whilden Associates
698 Holly Drive North
Annapolis, MD 21401-5502
(301) 757-9488

Agricultural Research Institute
9650 Rockville Pike
Bethesda, MD 20814
(301) 530-7122

American Mosquito Control Association
P.O. Box 5416
Lake Charles, LA 70606-5416
(318) 474-2723

American Mushroom Institute
907 E. Baltimore Pike
Kennett Square, PA 19348
(215) 388-7806

Appropriate Technology Transfer for Rural Areas
P.O. Box 3657
Fayetteville, AR 72702
(501) 442-9824

Bio-Integral Resource Center
P.O. Box 7414
Berkeley, CA 94707
(510) 524-2567

Committee for Sustainable Agriculture
(Agricultural Science) (CSA)
P.O. Box 1300
Colfax, CA 95713
(916) 346-2777

Electronic Pest Control Association (EPCA)
710 E. Ogden, Ste. 113
Naperville, IL 60563
(708) 369-2406

Integrated Plant Protection Center
Oregon State University
Cordley Hall 2040
Corvallis, OR 97331-2915
(503) 737-3541
FAX: (503) 737-3080

Intermountain Research Station
324 25th Street
Ogden, UT 84401

Interstate Professional Applicators Association
(Pest Control) (IPAA)
P.O. Box 1377
Milton, WA 98354
(206) 922-9437

National Animal Damage Control Association
(Pest Control) (NADCA)
Rt. 1, Box 37
Shell Lake, WI 54871
(715) 468-2038

National Pest Control Association (NPCA)
8100 Oak St.
Dunn Loring, VA 22027
(703) 573-8330

Pacific Northwest Research Station
33 S.W. First Ave.
Portland, OR 97204

Pacific Southwest Research Station
P.O. Box 245
Berkeley, CA 94701

Professional Lawn Care Association
of America (PLCAA)
1000 Johnson Ferry Road, N.E.
Suite C-135
Marietta, GA 30068
(404) 977-5222

Rocky Mountain Forest and Range
Experiment Station
240 West Prospect Street
Fort Collins, CO 80526-2098

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