An Economic Model for Estimating the Cost of Detoxifying Pesticide Containers

L. Eugene Johnson

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An Economic Model for Estimating the Cost of Detoxifying Pesticide Containers

By L. Eugene Johnson and John E. Waldrop
AN ECONOMIC MODEL FOR
ESTIMATING THE COST OF
DETOXIFYING PESTICIDE CONTAINERS

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Foreword

No approved disposal methods for unused pesticides and their containers were available to farmers and other users at the time this research effort was initiated. Therefore, a method for evaluating costs and other effects of alternative detoxification plans was needed. The Environmental Protection Agency now has indicated that unused pesticides, pesticide residues, and pesticide containers may be disposed of in landfills approved for disposal of hazardous waste. Specific instructions for such disposal are given on the label of the containers. The effect of this disposal method has reduced the urgency for the kinds of empirical analysis suggested in this report.

However, research methods and results contained in this report should be useful to researchers and others interested in environmental quality problems. The approach and methods of analysis are appropriate, with minor modification, to a wide range of environmental pollution problems.
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AN ECONOMIC MODEL FOR
ESTIMATING THE COST OF
DETOXIFYING PESTICIDE CONTAINERS

Environmental pollution has been a social problem of mounting concern in recent times. Differing views of pollution have been aired, at times in highly emotional debate. Now debate is less prevalent but policy-makers still must ponder the question—how much of our resources is society willing to devote to alleviating environmental pollution problems?

Complete elimination of waste materials would be extremely costly. Likewise, if no charge is made against the assimilative capacity of the environment, unacceptable levels of pollution will continue. Policy-makers must select a position between these extremes that is ultimately agreeable to society. Determining the combination of resources to devote to a better environment will require the best available decision inputs.

Commercial agriculture pollutes the environment in various ways—including soil erosion, plant residues, pesticide use, chemical fertilizers, animal waste, and the practice of discarding pesticide containers still containing varying amounts of technical materials.

1/ The term "pesticide is commonly used to refer to the whole family of agricultural chemicals or economic poisons which include any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any insects, rodents, nematodes, fungi, weeds, and other forms of plant or animal life and also those substances which act as regulators of plant growth, as defoliants, and as desiccants (36).
Many unused pesticides and their containers cause long-lasting contamination and their harmful effects have been publicized repeatedly as being in conflict with some of society's goals.

The Problem

Pesticide users are confronted with the problem of disposing of unused toxic chemicals and their containers. One course of least resistance (least cost to the individual decentralized decision unit), is to randomly discard containers. However, pesticide pollution has invoked some reactions that could result in costly restrictions on agricultural production.

Currently the only EPA approved procedure or method available to pesticide users for disposing of unused chemicals and their containers is in landfills approved for disposal of hazardous wastes. Therefore, it is desirable to evaluate alternative methods. The 1972 Pesticide Act obligates the government to assist in disposal of pesticide containers, adding further impetus to researching this problem (35, p. 9).

Various methods of detoxifying pesticides and pesticide containers are presently being researched. Preliminary results indicate that

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2/ The terms "pesticide containers" or "containers" are used instead of "unused chemicals and their containers" throughout the remainder of this study. It should be noted that it is the unused chemicals or pesticides remaining in the containers which society wishes to detoxify and there is no particular interest in the containers themselves.

3/ Underlined numbers in parentheses refer to items listed in Selected Bibliography.
some techniques have the potential to detoxify pesticide containers with little harmful effect on the environment.

The development of a safe detoxification method solves only one aspect of the pesticide container problem. Irrespective of the procedure one might select or develop, pesticide containers must be located, identified (size, type of chemical, etc.) and assembled before detoxification can take place. The number and geographic distribution of the containers involved make collecting pesticide containers a monumental problem. Also, the costs involved will be substantial and could cause problems that may be unacceptable to consumers.

More than 100 firms in the United States produce about 1,000 basic pesticide chemicals that are formulated into about 50,000 registered commercial pesticide products (10, p. 39). Jansen estimated that nationwide in 1963 the pesticides (fungicides, herbicides, and insecticides) used by farmers were packaged in about 165 million containers (18, p.35)—and that this figure had increased to about 240 million by 1968. If the number of containers generated from industrial, governmental, and urban use are added, the true scope of the problem is revealed.

An economic evaluation of alternative plans for assembling and detoxifying containers will be needed to assess alternative detoxification techniques. However, plans for assembling and detoxifying pesticide containers must be developed before an economic assessment of alternatives can be made. Total cost of detoxifying containers may vary significantly with the design of alternative detoxification plans. Also, the plan
selected will influence how costs are distributed among sectors of the economy.

Basic data needed in conducting an economic evaluation are not yet available. Detoxification techniques still are being researched. But, the number, type, size and location of pesticide containers by county, state, and region are not known and requirements for land, buildings, equipment, and other facilities needed in assembling and detoxifying containers have not been developed. This lack of information precludes any detailed empirical economic analysis.

Purpose and Objectives

The purpose of this study was to develop an economic model for estimating the cost of detoxifying pesticide containers and, where possible, identify the incidence of costs associated with alternative detoxification plans. Specific objectives were:

(1) To develop a conceptual economic model that specifies data needed to estimate the cost of detoxifying pesticide containers.

(2) To present alternative detoxification plans—specifying the functions and factors that influence cost—and, where possible, identify the incidence of costs associated with each alternative plan.

(3) To evaluate alternative detoxification plans and make recommendations for further research.
Scope and Method

Benefits and costs of improving the quality of our environment accrue to society. Therefore, choice of the level and combination of resources to devote to a better environment should be based on accurate estimates of the benefits and costs of alternative methods of pollution abatement. Estimating benefits and costs is, however, one of the most difficult tasks, both in theory and practice, that the researcher must accomplish in reaching solutions to pollution problems.

Environmental problems are typically externality problems and our system of markets fails to generate and convey much of the basic information necessary for their solution. Environmental externalities generally have been ignored by scientists and the public in general, therefore, there has been little pressure for systematic collection and reporting of basic data on quantities of pesticides being used, residues of pesticides in various elements of the environment and the incidence of environmental damage. Second, if basic data were available it would be impossible to make the required interpersonal utility comparisons necessary for estimating many benefits and costs. These benefits and costs are therefore considered intangibles since they cannot be readily translated into a common value estimate. Third, investment decisions generally require discounting future costs and benefits to the present, or some other common time period. Decisions concerning alternative allocations of resources to solve environmental problems require discounting benefits and
costs that accrue to future generations. At present the data and
techniques needed for quantifying many benefits and costs that
accrue to the present generation—much less those that will accrue
to generations yet unborn—are lacking.

An alternative may be to identify those variables that can be
quantified to provide a foothold for societies' assessment of
alternative courses of action. Economists are equipped, and have
some information available, to deal with the tangible costs of
environmental improvement; i.e. costs of the resources that must
be diverted from other uses can be estimated in most instances.
Objective estimates of tangible costs—along with subjective estimates
of other costs and benefits as expressed through the political
process—provide a basis for rational choice of pollution abatement
investments.

Society can make decisions as to what it is willing to forego
in providing environmental improvement, and identifying the
incidence of costs provides society a basis for expressing their
desired distribution. This approach may not result in an optimum
allocation of resources, but it certainly is in line with efficient
resource use.

Ultimately, society benefits and society must pay the cost of
improving the environment. Whether taxes are collected and an
improved environment is provided as a government function or whether
legislation is enacted to make private parties internalize these
costs with resultant higher consumer prices, the cost of providing environmental goods cannot be ignored.

Limited information available on the pesticide container problem requires that a conceptual rather than empirical economic approach be used. Major functions required in assembling and detoxifying pesticide containers are outlined in this study. Economic variables and relationships that influence the cost of performing these functions are identified and form the basis for developing the economic model.

A conceptual model of the major cost elements of a pesticide container detoxification system is delineated. A hypothetical situation is specified to illustrate use of the model in conducting a detailed economic evaluation of a detoxification technique. The system developed includes plans for collecting, transporting, storing, and detoxifying containers, along with a management system to coordinate and supervise operation of the system. Research techniques and procedures for estimating the cost of each phase of the specified detoxification system plan are considered.

Alternative plans are developed to illustrate the effect of changes in the detoxification system. This procedure is designed to emphasize the importance of evaluating alternatives as opposed to accepting a plan that may only meet feasibility criteria. Much of the original detoxification system is retained in developing alternative detoxification plans.

Alternative plans consist simply of changing various parts or phases of the original system. Changes in functions and factors that
influence cost are identified and the incidence of costs of each plan is identified where possible. Detoxification plans are evaluated and recommendations for further research are made.

THE ECONOMIC SETTING OF ENVIRONMENTAL POLLUTION PROBLEMS

Man's survival always has depended upon his ability to adapt to and work fundamental changes in his environment. The planet on which he lives is not static, but is conditioned by continual change. His activities are mere responses to change, whether natural or man made, and result in further change. Adjusting to this continual change, man strives toward using his limited resources to attain the greatest level of satisfaction for himself. The influence of each individual guided by his own interest can, under specified conditions\(^1\), result in creating the greatest level of welfare or well being for society. One such condition is that each individual account for all costs (including external costs) associated with his activities.

Using our resources to produce high and rising levels of income often produces "side effects" or "residuals" that are incidental to the main purpose (16, p. 1). These side effects go beyond the economic unit that produces them and may affect others in important ways—some favorable and some unfavorable. The presence of unfavorable side effects or residuals may create problems of environmental pollution.

Taylor defines environmental pollution as those interactions of men with their physical surroundings that result in diminished levels of well being (33, p. 6).

Everyone in some way contributes to pollution by generating residuals. Dales states that, in general terms, the economic process of a society may be thought of as a continuous flow of materials (9, p. 1). Vegetable, mineral, and animal materials are taken from the environment and transformed into economic goods by man. He extracts services from these goods and the goods undergo physical or chemical transformation, resulting in residuals that are discarded into the environment. The production process that completes this cycle generates additional wastes that are discarded into the environment.

Our natural environment has the capacity to assimilate many of these wastes. Waste products were limited and readily absorbed by nature so that they were less noticeable in earlier generations. Today, there is increasing concern that the rate, concentration, and stability of many wastes are exceeding nature's assimilative capacity in many areas.

Environmental Pollution in a Market Economy

Environmental pollution is not peculiar to any form of government nor is it restricted to any level of wealth. Historically and geologically the environment has been in an ageless, natural flux and one can find examples today of how nature, even in the absence of man, modifies itself in directions dangerous both to itself and
to man (37, p. 46). Ruff disposes of some popular myths stating that pollution can no longer be blamed on affluence since many of our poor and developing countries exhibit conditions where pollution runs in the streets (29, p. 10). Nor can pollution be blamed on the activities of greedy capitalists since many of the once beautiful lakes and rivers of the Soviet Union are now open sewers and cesspools. Likewise, some of the world's dirtiest air and water can be found in East European cities, which are neither capitalistic nor affluent. Instead, Ruff concludes that it seems more probable that those countries having ample resources, a high level of technology and a democratic form of government that reflects the views of its people will turn out to be the cure more than the cause of pollution.

Dealing meaningfully with policy issues concerning pollution requires a concept of the functioning of the economy. Economic systems throughout the world share a common problem—that of allocating relatively limited resources among unlimited wants of people. Every economic system must provide some way of doing three things: (1) getting goods produced; (2) determining what share of the total product each person shall have; and (3) regulating the consumption of goods (31). All economic systems are to some extent mixed; i.e., government and the price system have varying roles in performing these functions (25). Our democratic form of government in the United States provides a mixed capitalistic economic system to organize and regulate the production, distribution and consumption of goods.
Basically, our economy is a market economy. Under certain conditions a market economy will produce precisely those goods and services wanted by consumers and produce them in just the quantities wanted and at minimum cost (23, p. 75). The decision-making process in a market economy is highly decentralized. Individuals are free to buy and sell goods and services and to own and organize the means of production for private gain. Prices determined by supply and demand in competitive markets provide the basis for decisions on what goods and services to produce and how resources are allocated to produce them. In most instances, competitive prices convey the necessary information for making optimal decisions (23).

Consumers express their individual tastes and preferences by using their limited income dollars like votes to inform producers of the goods and services they prefer. Each consumer attempts to achieve the maximum level of satisfaction from a given amount of income.

Producers seeking to maximize profits weight relative production costs against relative prices when deciding when and how much of each good and service to produce. Each producer considers his own resource position, market prices, alternative product resource requirements and consumer demands in making this decision. Production decisions depend largely on the performance of the price system.

It is generally held that individual interests do not conflict with each other in an ideal market economy (14). Available resources will be allocated to maximize welfare, given the distribution of
income, if producers and consumers act rationally in attempting to achieve the highest level of individual satisfaction (22).

However, welfare is not maximized where there is a divergence between private costs and social costs. The technical conditions of production and consumption in an ideal market economy require that the costs and benefits of performing any activity fall upon the acting party (22). Our economy departs from this ideal. Control over the use of economic goods or resources is not always maintained or accounted for by markets, and the activities of one economic unit may result in benefits or costs to other units.

Environmental Pollution as an Externality

A producer's profit maximizing decisions may unintentionally result in the shifting of some production cost to someone else. For example, a pesticide user may decide to discard unused pesticides in a way that eventually allows the pesticide to enter a water course---killing fish and resulting in reduced income to fisherman, sellers of fishing supplies, boat manufacturers, and others. If he fails to pay for dumping of such wastes, his private production cost and the social production cost diverge and resource allocation is distorted even though markets may function in an otherwise ideal manner.

External effects of this kind usually are referred to as "spillover effects", "side effects", or more traditionally, as "externalities". External effects arise whenever a production function, or a consumption function, depends directly upon the activity of others (26, p. 2). Randall states that an externality exists whenever the utility of one
or more individuals is dependent upon, among other things, one or
more activities which are under the control of someone else (27, p. 175).

Failure of our market economy to meet optimum efficiency when
private and social cost diverge does not imply that decisions based on
private cost calculations should be replaced by some alternative
decision mechanism. Usually external effects are not large enough
to negate the overall tendency toward optimal resource allocation
(23). However, there is increasing concern that pollution effects
may be substantial enough to warrant corrections through public policy.

Property Rights to Environmental Resources

The major social concern is pollution of land, air, rivers,
lakes, and oceans. Rights to use these resources may be held by
everyone in common or ownership simply may not be specified by
law (17). Our system of markets is relatively efficient in handling
extractive, harvesting, processing, and distributional activities
where private property rights are well defined (21). However, the
return of most residuals to the environment impinges heavily upon
common-property resources and failure to charge for the use of them
may result in over-use. These common property resources are of
great and increasing value in developed countries. The capacity of
the environment to assimilate some residuals is finite and should
be allocated in a manner consistent with efficient allocation of
other scarce resources. With today's growing population, increased
affluence, and higher population densities in some areas, increased
interest is being directed toward developing more adequate policies for use of common property resources.

Solutions to Environmental Quality Problems

Most of the environmental quality problems publicized in the popular literature are the result of external diseconomies that may be classified as Pareto-relevant externalities. An externality is defined as potentially relevant when the extent of an activity generates a desire by the externally damaged party to modify the behavior of the damaging party, through trade, persuasion, compromise, collective action, etc. If the extent of the activity exerts no such influence it is considered irrelevant. A Pareto-relevant externality is one where an activity may be modified in a way that makes the externally-affected party better off without adversely affecting the acting party. The distinguishing characteristic of Pareto-relevant externalities is that trade offers potential gain for both parties.

Improving the quality of the environment requires the modification of activities that produce external diseconomies. Randall states that, if one wishes to modify the behavior of an economic unit, one must modify the incentives facing that economic unit so that the preferred behavior becomes more appealing to it (i.e., more pleasant, more profitable, or both). He lists three broad classes of methods for solving environmental quality problems: (1) market solutions, given a set of liability laws which serve as a starting point for bargaining; (2) systems of per unit taxes, charges, fines or subsidies; and (3) systems of standards, enforced by penalties or
imprisonment. Randall considers only market solutions. However, other solutions deserve some discussion. It seems appropriate to combine (2) and (3) for discussion in this study.

**Market Solutions**

Since the 1960's, increased attention has been given to market solutions of externality problems. Coase (7) perceived that, with perfect competition and zero transaction costs, negotiations between the parties involved in an externality would result in optimum resource allocation regardless of the starting point established by the liability law. The attractiveness of this approach is that it relies on the market to establish the price of an externality. All society has to do is to establish the rule and any rule will result in the same Pareto-efficient equilibrium solution.

An infinite number of rules is conceivable; however, two extreme examples of such liability rules are the no-liability rule and the full-liability rule. Under the no-liability rule any amount of external diseconomies may be created without penalty. The affected party has an incentive to offer a bribe to induce the acting party to reduce the output of external diseconomies. The full-liability rule specifies that no externality will be allowed without permission

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2/ Transactions costs as defined by Randall (27) are those costs of making and enforcing decisions. Included are the costs of obtaining information, establishing one's bargaining position, bargaining and arriving at a group decision, and enforcing the decision made. Any method of modifying externalities will involve some transactions costs. In many instances the size of the transactions costs may become a major factor in the selection of an efficient method of solution of any particular externality problem.
of the affected party, thus creating an incentive to offer compensation to induce the affected party to accept a certain amount of externality.

Randall (27), using a mathematical analysis with derived supply and demand functions for the abatement of an externality, concluded that different liability rules resulted in different allocations of resources in production and consumption. He also stated that, unless ways can be found to reduce the transactions costs associated with market solutions, such solutions—even under the full-liability rule (acting party making payments to the affected party)—will remain the plaything of academic economists and be largely ignored by policy-makers and the general public.

Kneese (21) adopts a similar argument and points out some weakness of discussion that focus on two-party, pollution-type externality situations. Externality situations in the literature generally are concerned with two individuals or two firms, with both parties having equal economic power and full information about their own and their adversaries' position in an economic setting where the allocation of resources is in every other aspect optimal. He states that, with regard to environmental pollution, this situation is highly unrealistic. Typically, environmental pollution problems involve one or more sources of pollution, usually associated with a well-organized economic interest, that affect a large and diffuse group of parties whose individual interests are affected relatively little. For example, pollution by a chemical manufacturer or a pulpwood mill may affect many hundreds of fishermen few of whom find it worth their while to bargain or even generate the required information. No bargaining
occurs since the cost of organizing the fisherman may be prohibitive.

Some externality questions in isolated cases have been resolved by market solutions but it seems very unlikely that market solutions will be put to widespread use in solving environmental pollution problems.

**Charges and Standards**

A public authority establishes charge schedules and anyone discharging certain wastes into the environment would be required to pay a prescribed sum for each unit of waste discharged under a system of effluent charges. Those generating wastes would compare the cost of using the environment for waste discharge—as reflected to them by the charge schedule—with the cost of handling their waste disposal problems in some other way.

The choice of means for dealing with the waste would be left to the discharger. He may treat the waste, recycle it, store it, or find methods of production that reduce the volume of waste generated. Those generating wastes will reduce their discharge of waste as long as the marginal cost of doing so is less than the price or marginal cost of discharging waste into the environment.

The effluent charge should be set to equal the marginal or incremental damage caused by the pollutant, as measured in dollars. Determining the incremental charge requires information about the marginal damage from additional pollution and the marginal cost of reducing pollution. Such information is difficult to come by and in most instances is not available.
Environmental quality levels set by the government or other authority can be attained by adjusting the charges. Proponents of the effluent charge system cite that it provides a continuing incentive to abate pollution and ties environmental costs to the processes that generate the pollution (23,§). The effluent charge system establishes a price for using environmental resources and also generates additional revenue.

The effluent-standards approach relies upon a public authority to set standards for each firm's discharge of waste. Setting standards is an attempt to enforce a collective judgement. This approach is generally favored because it provides an avenue of legal action against polluters. Setting standards for each firm makes the amount of waste discharged by all firms into a river or an air basin consistent with a previously-established environmental quality level. Once a standard is set, each firm can chart its own course by choosing the best mix of process changes, improved management and effluent treatment needed to meet the standard. A firm that discharges waste in excess of the established standard faces the threat of judicial proceedings to enforce compliance with the standard or to secure penalties for such violation.

The application of either the effluent charge or effluent-standard method involves a maze of complex problems. Enforcing effluent standards remains an uncertain and continuing problem. In most instances methods for measuring and tracing sources of pollution have not been adequately developed. The judicial process works slowly and there are many opportunities for delay along the path of due process of law.

In most, if not all, cases the information for setting effluent standards is incomplete. Firms using the same air basin may be required to reduce discharges proportionately although they face different levels
of abatement costs. Where costs differ, the same environmental quality could be attained at lower costs by having the sources with low control costs undertake more control than the sources with high costs. Many, including the owner, might think it unfair to penalize a plant with low control costs which result from efficient pollution control measures by imposing an especially tough standard on such a plant.

Developing standards that reflect the cost of reducing pollution requires detailed information on costs at each individual source. Likewise, selecting a least-cost effluent charge that will exactly attain the environmental quality level desired requires information on the costs of reducing discharges at all sources. Such information is not presently available and would be costly to obtain.

Summary

In presenting various methods for solving pollution problems, many authors focus narrowly and abstractly on the general method and give little attention to the involved process of applying a particular method or to the consequences that may arise from its use. For example, if environmental quality levels are not being met, some argue that effluent standards should be more restrictive. A firm faced with increased standards may decide to discontinue its operation, thus decreasing substantially the revenue of a small community. As a result many people may have to seek jobs in other areas and the value of homes, land, and other property may decrease substantially. In resolving one externality situation other external effects are created. Decisions concerning the use of alternative methods of
reducing pollution should, therefore, consider the direct cost associated with a particular method and the total costs that society must absorb.

A CONCEPTUAL MODEL TO ESTIMATE THE COSTS OF DETOXIFYING PESTICIDE CONTAINERS

Formulation of a model to estimate the costs of detoxifying pesticide containers requires the identification and specification of the major functions performed in assembling and detoxifying containers. These functions and the requirements for performing them influence the cost relationships and the structure of the model. Functions that must be performed are, in turn, determined by currently-available detoxification techniques.

Current Status of Detoxification Techniques

Much of the detoxification research completed to date deals with the technical feasibility of reactions to neutralize pesticides. No recommendations have been developed for large-scale application of such techniques.

Biological, chemical, and thermal methods of pesticide detoxification are presently being researched. Preliminary results indicate that two feasible methods are chemical reactions and incineration (20).

Some success has been achieved in decomposing small quantities or weak solutions of certain pesticides with soil microorganisms. However, the decomposition process generally proceeds too slowly to be considered practical for detoxifying large quantities of pesticides.
Experiments with the use of chemicals revealed that no single chemical was completely effective in decomposing pesticides (5). The wide range of molecular structures that make up the numerous pesticide formulations makes it difficult, if not impossible, to discover a single agent that would be universally effective. However, some pesticides have been partially degraded with mixtures of chemicals indicating that chemicals offer a potential for detoxifying some classes of pesticides (5).

The most feasible method for disposal of pesticide wastes and pesticide containers appears to be incineration (30). It has been determined that a temperature of 900° Centigrade, easily attainable by most commercial incinerators, is sufficient to destroy pesticides. Incineration is an adequate detoxifying technique when provisions are made for trapping the toxic effluents that otherwise would be discharged into the atmosphere.

A problem of both the chemical and incineration techniques is the disposal of residues from these processes (20, 5). Research is continuing on these techniques and on methods for disposing of the residual materials.

Researchers have concluded that incineration, chemical treatment, and microbial degradation ultimately may be employed in some phase of a workable pesticide disposal process (30). The conceptual model presented in the following section is not developed for a specific detoxification technique. Instead, it is concerned with the functional
aspects of the problem and should be applicable to any detoxification method.

The Model

The cost of detoxifying pesticide containers depends directly on the specification of the detoxification plan or system. An infinite number of detoxification plans, all different in some detail, is conceivable. The conceptual model presented here is derived from the basic functions associated with detoxification and forms a skeletal framework for developing and estimating the cost of many alternative detoxification system plans. The conceptual model developed can be expressed as follows:

\[ CPDS = f(CC + TC + DC + SOMC) \]  

where:

- \( CPDS \) = cost of the pesticide detoxification system
- \( CC \) = cost of collecting pesticide containers
- \( TC \) = cost of transporting pesticide containers
- \( DC \) = cost of detoxifying pesticide containers and disposing of residual materials, including all plant costs
- \( SOMC \) = cost of operating and managing the pesticide detoxification system

These components of cost can be further specified in a conceptual sense as follows:

\[ CC = c(V, NCP) \]  
\[ TC = t(V, DUP, DCP) \]  
\[ DC = d(V, NDP) \]  
\[ SOMC = s(AC, REG, COSUP) \]
where:

\[ V = \text{volume (number, type, size, etc.) of pesticide containers.} \]  
Pesticide containers must be transported from use locations to collection and detoxification points. Volume will influence collection, transportation, temporary storage and detoxification costs.

\[ NCP = \text{number of pesticide container collection points in the detoxification system.} \]

\[ DUP = \text{distance from pesticide use locations to pesticide container collection points.} \]

\[ DCP = \text{distance from collection points to pesticide container detoxification and disposal points.} \]

\[ NDP = \text{number of pesticide container detoxification and disposal points.} \]

\[ AC = \text{accounting activities associated with the detoxification system.} \]

\[ REG = \text{regulatory activities associated with the detoxification system.} \]

\[ COSUP = \text{coordination and supervisory activities associated with operating and managing of the detoxification system.} \]

The functional cost relationships presented represent only the bare bones of the model; thus, to fully understand the logical basis and the underpinnings of the model one must consider the nature and setting of the pesticide container problem.

**Nature of the Pesticide Container Problem**

The pesticide container problem is similar in many respects to the basic problems associated with the processing of many agricultural products. That is, farm products must be assembled, transported, and processed. Raw farm products are assembled or collected on farms at harvest and are usually transported to local marketing facilities. The local marketing points serve to assemble the
production from many farms. At these points the raw products may be graded, partially processed, or temporarily stored before being transported to major processing facilities. Generally, processing involves some change of form or added service as raw products are converted into the final goods consumers demand.

Correspondingly, pesticide containers associated with farm use are located on or near the farm; thus containers, like farm products, are scattered over a large geographic area. If containers are to be detoxified, some system similar to the assembly of farm products must be developed to collect and aggregate these containers.

The basic functions parallel each other; pesticide containers must be collected, transported, and detoxified—while farm products are assembled, transported, and processed. Thus, the processing industry can serve as an excellent guide for designing a model pesticide detoxification system.

Cost Relationships

Efficient organization of processing plants, whether for pesticide containers or other products, involves the simultaneous consideration of three main elements of total cost: (1) the costs of collecting the material to be processed from scattered origins to the point of plant location; (2) the costs associated with operating the plant; and (3) the cost associated with transporting the processed product to market (2). These elements of total cost can be expected to vary with variations in the total volume of product processed; therefore the most efficient organization will involve the selection of plant volume that tends to minimize these combined costs.
Collection cost tends to increase with distance. Increasing processing plant volume to capture expected economies of scale may require the collection of materials from more distant areas, thus increasing the total cost of collection. Therefore, efficient organization of processing plants involves a balancing of the expected decreasing average processing cost against the increasing collection cost. Additionally, these basic cost relationships influence the number, size and location of processing plants within a given area.

Although the cost relationships associated with assembling and detoxifying pesticide containers have not been specified or quantified, it seems reasonable to assume that these cost relationships would be similar to those of agricultural processing industries.

Detoxification of pesticide containers does not involve the marketing of any product but the disposal of the residue will likely involve many of the functions common to product distribution—transportation and handling, for example.

Organization of Resources

Since many of the functions associated with the processing of farm products seem applicable to the pesticide container problem, a similar bundle of resources may be required for detoxifying pesticide containers. However, unlike the processing of farm products, the end product of detoxification—a better environment—is not readily exchanged in the market place. Our system of markets is relatively efficient in handling harvesting, processing, and distributional activities where private property rights are well defined (21).
In most instances, rights to environmental resources are held by everyone in common or are simply unspecified by law (17). Therefore, there is little incentive on the part of the private sector to assign and efficiently organize the resources needed for detoxifying pesticide containers.

In other instances, where the good in question is of public interest (e.g., national defense, weather information, etc.), society has deemed the production of these goods a function of government. Whether pesticide containers are detoxified in government-owned and-operated facilities or whether society enacts laws to motivate private citizens to establish and operate detoxification facilities, an overall management system will be required to enforce laws and to coordinate and supervise many of the activities associated with the operation of a pesticide detoxification system. Thus, resources must be assigned and organized to accomplish this phase as well as other phases of a detoxification system. Use of resources for this purpose precludes their use for producing other goods and services and this seems sufficient to warrant adequate attention to insuring efficiency in producing the public good—environmental quality.

Scope of the Model

The model was purposely specified in general form for versatility—allowing for alternative detoxification systems to fit different situations. Although the problem situation assumed for demonstrating the model concerns agricultural pesticide containers, the model is
equally appropriate for dealing with other groups of harmful chemicals or pesticides, such as those used by households, industry, pharmaceutical firms and others, or for detoxifying a banned pesticide that might presently be stockpiled. The model is not linked to any particular geographical area and is easily adaptable for developing alternative detoxification systems at the sub-state, state or regional level.

Only the key variables that influence the cost of each segment of a detoxification system are specified in the model. Others may be revealed only when specific plans are developed. A hypothetical pesticide detoxification system with each element of the model considered in detail is presented in an appendix to this report.

**ESTABLISHING THE INCIDENCE OF COSTS ASSOCIATED WITH ALTERNATIVE PESTICIDE DETOXIFICATION PLANS**

An idea central to the study is that many of the costs and benefits associated with pollution problems are external to the market. Johnson (19) states that the market ordinarily has gone about as far as it can go toward solving pollution problems without assistance in the form of non-market adjustments. Consumers and producers have not made the required changes (internalizing externalities through negotiation, litigation or other means) because of costs and benefits external to their private calculations. However, when non-market adjustments are made to internalize previously external costs, this automatically throws the market into a disequilibrium which leads, in turn, to market adjustments. Therefore,
it is important to consider the impact that alternative pesticide detoxification plans may have on various sectors of the economy.

Considering alternative plans makes it possible to determine how the functions and factors that influence the cost of detoxifying containers are changed. The incidence of costs by sectors also can be identified for each alternative. By tracing through the effects of each alternative plan, an assessment can be made as to the impact each plan may have on those sectors immediately concerned with the marketing and use of pesticides as well as other sectors of the economy.

Incidence of Costs

The concepts developed in the appendix assumed a system operated by a government agency. Primary reliance is on direct regulation requiring pesticide users and marketing firms to perform certain activities. The main functions associated with this system are collection, transportation, detoxification, and operation and management. The costs of performing these functions are incurred by three sectors—the pesticide marketing sector, the farm sector, and the government sector.

Pesticide Marketing Sector Costs

Pesticide manufacturers, wholesalers, and retailers are required to assimilate accounting data for the overall detoxification management system. At each level these firms incur additional operating costs in supplying this information. Performing these functions will require additional labor and possibly the hiring of additional personnel. Marketing firms will attempt to shift these added costs
down the marketing channel. As a result of the shifting of these costs, pesticide prices can be expected to increase at the retail level.

Farm Sector Costs

Farmers are required to perform a basic collection function by transporting containers from use locations to county collection stations. They incur the costs associated with transporting containers as well as an opportunity cost associated with the time required. However, freedom to select an appropriate time for turning in containers and convenience of the collection station should contribute toward minimizing the cost of performing this step in the collection function.

Requiring farmers to perform these activities is not expected to significantly increase costs at the farm level. However, the farmer's costs may increase as a result of the requirements placed on the pesticide marketing sector.

Government Sector Costs

The major bulk of the functions and activities required in detoxifying pesticide containers is performed by a government agency. This agency is responsible for establishing the physical facilities and operating the entire detoxification system. These activities include operating container collection stations, transporting pesticide containers to detoxification plants, operating detoxification plants, and managing the operation of the entire detoxification system. The funds needed to operate the detoxification system are
from the public sector. Other costs of enforcing regulations for implementing a system to detoxify pesticide containers will place added burdens and costs on various levels of enforcement agencies and judicial institutions, placing further demands on the public sector.

Alternative Plans

It is obvious that the design of the system and the laws and regulations required to implement it influence the costs involved and the incidence of costs among various sectors of the economy. Changes in the detoxification system will certainly influence container detoxification costs as well as the incidence of costs; therefore, it is important to consider alternative detoxification plans.

The hypothetical detoxification system presented in the appendix is retained in developing alternative pesticide detoxification plans. Alternative plans consist simply of changing various parts or phases of this system.

Alternative A

A major problem in implementing a plan that uses direct regulation to accomplish the initial collection of pesticide containers is the enforcement of such regulations. It was assumed that a computerized accounting system would be employed to assist those in charge of enforcing regulations. The accounting system is designed to account for containers from pesticide manufacturers to final container detoxification. Although such a system may be quite
effective and also generate valuable managerial information, some may question the cost and need for such an elaborate accounting system.

One alternative to direct regulation would be to establish a system of deposits on pesticide containers. Deposits would be collected by pesticide retailers at the time of purchase and redeemed when containers are delivered at county collection stations. Failure to return any container would result in forfeiting the deposit and the schedule of deposits for various containers would be set high enough to insure their return. No proof of purchase would be required and anyone could turn in containers for the deposit. Some individuals may find it profitable to establish a scavenger service to collect containers for the deposit. Thus, the deposit system brings market forces into play and provides an incentive for pesticide users and the public in general to return containers to collection stations.

However, a deposit system does not operate without costs. By substituting the deposit system for the accounting system many functions, costs, and the incidence of costs will be changed and shifted within sectors and between sectors. Without specifying in great detail all aspects of operating the deposit system and without specific information concerning the demand and cost relationships faced by the firms involved, it is difficult to rigorously analyze the effects this plan may have on various sectors. Therefore, only a general treatment of these effects is presented.

Going from the original plan to alternative A shifts many functions and costs previously associated with the pesticide marketing
sector to the retail level. Pesticide manufacturers and wholesalers no longer incur added operating expenses previously required in supplying accounting data. Instead, pesticide retailers must now collect deposits as well as keep additional records. Performing these activities will certainly require additional time and, in some cases, may require the hiring of additional personnel by retail firms. It is reasonable to assume that managers of these firms, acting in a rational manner, will raise prices of pesticides to cover these added operating costs. Other firms, especially those whose sales of pesticides account for only a small percentage of total sales, may find these added duties and costs prohibitive and discontinue the sale of pesticides.

The public sector no longer pays for the accounting system. However, additional personnel will probably be required to operate county collection stations since these stations must now disburse deposits to those returning pesticide containers. These added functions will certainly require additional administrative duties and records. Performing these added activities will require additional man hours in processing each transaction as pesticide containers are returned to collection stations. Thus, changing the plan probably will result in higher costs of operating each county pesticide collection station. Although the funds previously allocated to the accounting system could be applied to operating the deposit system, estimates of the costs associated with each system are needed to determine whether this change in the plan
would result in a savings or an added expenditure of tax revenues from the public sector.

Requiring farmers to place a deposit on pesticide containers results in shifting additional costs to the farm sector. Farmers now incur an additional cost in having limited operating capital tied up in deposits. They also incur the same costs associated with transporting pesticide containers to county collection stations. Although the deposit is redeemed upon returning the container, farmers must forego the interest the deposited funds could have earned if invested or must pay interest on the borrowed capital used in making the deposits.

Thus, farmers are confronted with rising pesticide prices from two sources. First, they incur an opportunity cost associated with the container deposit, the net effect being an actual increase in the cost or price of the pesticide input. Second, pesticide prices have been increased as a result of increased costs associated with implementing the deposit system at the retail level.

Rising costs and prices in these sectors certainly will precipitate resource adjustments in these and other sectors of the economy (discussion concerning possible resource adjustments is deferred to a later section). Thus, determining how changing one phase or part of the detoxification system influences other sectors is important. Policy-makers should carefully evaluate many alternative plans, with special attention directed to the sectors affected, before arriving at final policy decisions.
Alternative B

To further illustrate the effects of changes in the detoxification system, an alternative plan is presented. Instead of establishing county collection stations, pesticide users are required to return containers to pesticide retailers. Pesticide containers are toxic and hazardous to handle but it may be discovered through research that, if certain procedures are followed and if specified facilities are available, waste pesticide containers can be safely returned to any point—even those located near populated areas. Containers will be picked up at periodic intervals and transported by truck to pesticide detoxification plants.

By shifting the container collection station phase of the detoxification system to pesticide retailers, added costs and functions are transferred to the pesticide marketing sector, especially at the retail level. Retail firms not only incur added costs for collecting containers but must also make added investments in buildings and equipment to handle and store containers while they await shipment to detoxification plants. The activities and the investments now required of pesticide retailers are considerably greater than those associated with retailers collecting container deposits.

Because of these added operating costs and investments in buildings and equipment, many pesticide retailers may discontinue handling of pesticides, especially the low volume dealers who sell pesticides only as a sideline or to accommodate their customers.
Firms with larger pesticide sales are more likely to continue operating and make the required investments in buildings and equipment, so long as these added expenditures can be recovered in the market through higher prices. Additional pressure to increase prices will also be brought about by other firms in the pesticide marketing sector. At each level—pesticide manufacturers, wholesalers, and retailers—added costs are incurred in supplying accounting data for the detoxification management system. Thus, pesticide prices may rise even higher.

The commitment of the public sector is reduced considerably by shifting much of the container collection function to pesticide retailers. However, costs associated with other functions performed by the government agency may increase. Changing the collection points to retail firms means a larger number of collection points from which containers must be picked up.

No specific count of the number of businesses that handle pesticides in Mississippi could be made but there were 1,535 business firms that handled hay, grain, feed, and farm supplies in 1967 (34). It is reasonable to assume that these firms also handled pesticides. If so, the number of collection points would increase considerably from the 82 county collection stations of the original plan. The larger number of stops and the re-routing of trucks could significantly increase the costs of transporting containers to detoxification plants. Also, additional expenditures will be incurred in inspecting the collection procedures and waste pesticide container storage areas of retail firms. On the other hand, by having more collection points
the amount spent on enforcing the return of pesticide containers may be reduced significantly, since collection points are now more conveniently located.

Farmers may return containers more willingly since containers are now returned to the retail firm. In most cases, this means shorter travel distance for returning containers. Although the farmer's cost of returning containers may be reduced, he can expect to pay higher prices for pesticides because of the costs shifted to the pesticide marketing sector. Higher pesticide prices will certainly affect resource allocation at the farm level and will influence the supply of food and fiber available for consumption.

Summary

Many functions, costs, and the incidence of costs are changed and shifted within and among sectors by changing various parts or phases of the original detoxification system. Developing the decision inputs policy-makers require will involve an economic evaluation of many alternative detoxification systems. At present, without estimates of costs, it is impossible to ascertain specific answers. Although the analysis presented is general, it seems evident that pesticide marketing firms will attempt to shift the costs imposed by the detoxification system. If these firms are successful, the costs associated with detoxifying pesticide containers will rest on the farm and public sector. Placing detoxification costs on these sectors could precipitate substantial resource
adjustments. Therefore, policy-makers must be made aware of the incidence of costs on these sectors.

POLICY AND RESEARCH IMPLICATIONS

Substantial resource adjustments may be involved in a public decision to detoxify pesticide containers. Therefore, it is important to consider policy implications. Further, the development of needed decision inputs for considering various plans of action for implementing pesticide detoxification policy will require additional research.

Policy Implications

Society ultimately will pay the costs of detoxifying pesticide containers, either through additional taxes or higher consumer prices. Therefore, it is in society's interest to minimize these costs for a given level of environmental quality. However, policy-makers must concern themselves not only with minimizing the costs of diverted resources but also with the costs attributable to the adjustments required by various sectors of the economy.

The detoxification system is assumed to operate essentially as a government function—much like the sanitation services of cities. Each city household creates residuals (garbage and sewage) and these are disposed of through public facilities operated by the city government on a fee basis. Requiring each household to have disposal facilities for disposing of its residuals would be an inefficient use of resources, since economies of scale are realized with larger sanitation plants. Additionally, it would be difficult to insure
that all residuals were treated and disposed of in a safe manner; thus health problems could arise.

The same line of reasoning can be applied to the pesticide container problem. Placing a tax or passing a law to encourage or require each pesticide user to detoxify his pesticide containers does not solve the problem. Presently there are no detoxification facilities available. Detoxification by incineration is still being perfected and it seems highly unlikely that researchers will, in the near future, develop a small, efficient, economical incinerator that each user could afford. Also, there are problems of safety and enforcement of pesticide-container detoxification at this level.

The detoxification system assumed is not operated on a fee basis but is offered as a public service. Some may be quick to point out that the operation of the system results in a subsidy to the farm sector. Many feel that each polluter should pay for each unit of pollution he creates. Therefore, the general public may resent paying taxes to induce someone to stop doing something it feels should not be done in the first place. In considering alternative detoxification plans it is evident that, by making a slight change in the system, many functions and costs are shifted among sectors. If the system is operated so as to transfer all costs to the farmers or so that all costs are placed on the agricultural sector, considerable adjustments in the production of food and fiber would result.
The agricultural sector often has been cited as more closely exemplifying pure competition than other economic sectors. Purely competitive firms are not large enough to significantly influence market price; consequently, farm firms attempt to maximize profits by adjusting resource use for a given expected price.

If farmers were required to pay the cost of the pesticide and all the costs associated with detoxifying containers, per unit cost of pesticide inputs would obviously increase substantially. Today's modern agricultural technology relies heavily on the use of pesticides and the short-run effect of a substantial increase in pesticide costs could force many farm firms out of production.

Although some resource substitution may be made to counteract the increasing cost of pesticide use, Headley and Lewis (15) point out that complementarities between inputs and pesticide technology must be recognized as one of a number of factors that shape the structure of modern agriculture. "Changes in public policy that drastically alter this technology could rescind recent advances in farming methods if they reduce the effectiveness of other inputs such as mechanical cotton pickers, if they occasioned disruptions of current interregional comparative advantage, or if they significantly affected the optimal scale of farming operations" (15).

Increases in market prices tend to lag behind increases in costs of production. Since farm prices are set by the market, individual farm firms simply cannot increase prices when faced with increased production costs. Instead they can only adjust the quantity produced.
The aggregate effect of a large number of firms reducing or discontinuing production because of increased production costs will reduce total supply of farm products. When market prices rise sufficiently to cover the added production costs, farm firms will again produce the quantity of farm products consumers demand. However, in the interim or adjustment period many farm firms may be forced to liquidate machinery, land and other resources. Later reinvestment in these same resources may occur if and when market prices have risen sufficiently.

This lag in price adjustments and the resultant disruption of food and fiber production will cause additional repercussions in other sectors. Investment and employment may be reduced, especially in those sectors that depend on agriculture as a market for their products or as a supply of their raw inputs. Thus, the abundant supply of food and fiber that many consumers take for granted and are so price conscious about could be severely affected by placing all costs of detoxifying pesticide containers on the farm sector.

Society ultimately enjoys the benefits of a better environment and thus must pay its cost either directly or indirectly. Therefore, in considering alternative plans of action for providing a better environment, society must be cognizant of the consequences of levying costs on various sectors of the economy in selecting the route used in purchasing environmental goods.

Results of this study indicate what could occur if all costs of detoxifying containers were placed on the farm sector. However,
without estimates of these costs no one can anticipate the magnitude of the increased cost to the farm sector and the resultant adjustments among other sectors of the economy. Likewise, without estimates of costs it is difficult to compare alternative detoxification plans.

No statement can be made as to whether the total cost of one plan is greater than another. All one can do at this point is consider the functions, duties and activities required of each sector and speculate as to the magnitude of the costs involved in performing them. However, in assessing alternative pesticide detoxification techniques, policy-makers must look beyond the technique itself and consider the entire detoxification system and its possible impacts.

Estimates of tangible costs of alternative detoxification plans can be calculated, guided by the model presented in this study. These estimates can strengthen economic analyses for providing policy-makers useful guidelines for making decisions about the pesticide container problem.

Research Implications

The potential impact of alternative policy measures for solving the pesticide container problem underscores the need for immediate attention to evaluating alternative pesticide detoxification techniques and delivery systems. Analysis of the pesticide container problem revealed many areas of needed research. Two specific areas of research are prerequisite to estimating costs and evaluating
alternative detoxification techniques: (1) developing estimates of the present and future expected number, type, size and location of pesticide containers and (2) establishing explicit specifications for collection stations, transportation requirements and detoxification plants.

Other areas of needed research pertinent to pesticide pollution (as well as most other environmental problems) are: (1) difficulties of measuring external effects and assigning values and (2) lack of a complete understanding of the technical and physical relationships of the environment.

Environmental problems are typically externality problems. In dealing with externalities the most difficult problems of measurement relate to the use of resources that normally are not assigned a value by the market system or for which willingness to pay cannot be readily imputed. Economic research generally has tended to ignore "externalities" but in recent years the literature has devoted more attention to this area. Current and many future social problems involve "external effects". Therefore, economic theory in this area needs to be refined. Special attention to solving empirical problems for identifying and measuring externalities is needed.

Research in ecology must be expanded. Aside from a descriptive understanding of food chains or networks, an understanding of how pesticide residues are passed around in the food networks is needed. Such knowledge is prerequisite to understanding the effects of given exposure levels on the environment.
Additional data on the extent, location and severity of agricultural pollution need to be developed. Little is known about the quantity of potential pollutants going into our environment and even less is known about the physical effects that are the outputs—even those that are acute and can be observed.

More information is needed on the costs to agricultural firms of alternative means of pollution control. Relatively little information is available on the reaction pattern to environmental control programs that might be anticipated from firms and groups in various representative situations.

In view of the complexity and interrelated aspects of environmental management, a systems approach may be the most appropriate method of researching many of these problems. Both the economic effects and environmental effects should be considered.

United States agriculture is the most efficient agriculture in the world. However, the structure of our agriculture, cultural practices, and recent advances in technology depend to a great extent on the use of agricultural chemicals. Recent progress in agriculture could easily be nullified if the inputs necessary for determining and implementing least cost environmental policies are not made available. Agricultural economists can play a vital role in developing these decision inputs, since their research generally includes evaluating alternatives for decision making rather than prescribing solutions to problems or determining policy.
Policies emerge from an aggregate level and should reflect the consensus of the citizenry. Many questions cloud environmental policies and these questions can be answered only through additional research. The land grant college system with its experiment stations and research staffs provides an already existing group of scientists to address these questions.

CONCLUSIONS

A major conclusion that can be drawn from this study is that detoxifying pesticide containers involves a myriad of complex problems and the costs associated with detoxification are likely to be substantial. Although unverified empirically, it seems evident that the costs of detoxifying pesticide containers and the incidence of these costs could cause drastic adjustments in many sectors of the economy, especially in the agricultural sector.

Many alternative avenues are available for shifting many of the costs of detoxifying pesticide containers to the most competitive sector of the economy involved—the farm sector. Shifting of these costs to the farm production sector could have rather substantial economic impacts on the production of food and fiber since price increases generally lag cost increases in competitive industries.

Policies that result in a cost burden to the farm sector could cause major disruptions, eventually resulting in a situation that could be very costly to society. Circumventing the potential problems requires policies designed to avoid drastic economic effects on the farm sector. Ultimately the benefits of pollution control accrue to society in general; therefore, society will pay these costs
either directly through taxes or indirectly through higher prices for Food and Fiber.

Additional research to develop estimates of costs of alternative detoxification systems could create information required for society to make better decisions about the pesticide container problem. The approach and conceptual model developed in this study provide an excellent guide for developing the needed decision inputs for evaluating alternative environmental policies.
APPENDIX

HYPOTHETICAL DETOXIFICATION SYSTEM

A hypothetical detoxification system was specified to accomplish two main objectives: (1) to describe a feasible plan for detoxifying containers and (2) to specify the requirements of the system so that incidence of costs can be traced.

Situation Assumed

The detoxification system detailed in this study is developed under the following assumptions: (1) a decision is made that detoxification of pesticide containers and unused chemicals will be required in Mississippi; (2) a government agency is delegated the responsibility for establishing and operating all the facilities necessary to collect, transport and detoxify pesticide containers within the state; (3) the agency has the authority to require pesticide manufacturers, wholesalers, retailers, and users to perform some activities associated with detoxification, although the government agency has ultimate responsibility for the system; and (4) pesticide containers will be detoxified by incineration techniques.

1/ Chemicals used in industry, home use, etc. may contribute more to environmental pollution than "agricultural chemicals". However, selection of the agricultural sector simplifies the problem of devising a detoxification system.
Functions of the System

The pesticide detoxification model specifies four major functions: collection, transportation, detoxification, and operation and management. Each function is considered in detail.

Collection

It is assumed that a pesticide container collection station will be established at each county seat. The station will be equipped with the necessary facilities to safely assemble, store, and load on trucks the pesticide containers used within that particular county. Collection and storage of pesticide containers will occur on farms, at county collection stations and at container detoxification plants.

Each pesticide user will be held responsible for collecting and transporting his own pesticide container(s) to a county collection station at his convenience within some specified time period. Collection and storage of containers on farms should not cause the farmer any problems or additional expense. Most farmers have a designated area for storing pesticides before application. This same area can be utilized for storing waste pesticide containers until the farmer selects a convenient time to turn in his container(s) at the county collection station.

The second phase of collection involves the establishment and operation of pesticide collection stations. These stations will serve in a manner similar to local marketing points involved in the aggregation of raw farm products, e.g. pooling stations used in
handling raw milk. The station's role in the detoxification system might best be understood by considering how the station is expected to operate.

Operation of each station will involve proper handling of, accounting for, and temporary storage of pesticide containers. At periodic intervals the containers accumulated will be loaded on trucks and transported to the detoxification plant. Accurate records will be kept on all containers and reports submitted to the central office in order to schedule pick-up of containers at the collection station.

The size of the collection station will depend on the present and future expected number, type, and size of containers to be collected within each county, or other appropriate area. Station sizes may vary since economies of size are expected. When the assumption of one station per county is relaxed, the number, size and location of collection stations are all variables which should be determined simultaneously in order to minimize the cost of collecting the containers. Additionally, the rate at which containers are generated and the rate at which the containers are moved to detoxification plants will also influence collection station size.

Location of the station will depend to some extent on its convenience to the farmer and on the degree of possible contamination to the surrounding area. Assuming some pesticide spillage will occur at the collection site, the land area must be selected and managed in such a way as to avoid contamination resulting from surface water.
runoff or percolation into ground water. Thus, the location selected must be on land of suitable quality and dedicated to long term use for this purpose. Zoning of the land and surrounding area may be required to insure against the development of residential areas or other heavily populated areas adjacent to the collection station. The site selected should therefore afford some degree of isolation. However, it should be convenient so as to encourage participation by farmers. An ideal location would be one that is somewhat isolated from yet within easy access to the center of business activity of the area served. Since the county seat is usually the focal point of business activity, farmers may make frequent trips to the county seat, thus making it a convenient site for turning in containers. In the future, other containers, such as those used for controlling household pests, may require detoxification, eventually making it a convenient site for all.

Generally, some of the requirements for physical facilities and operational needs of the collection station are:

Land a fenced area

Building a shed-type building with adequate space for specialized area

A. receiving and loading containers
B. office
C. storage

Utilities

A. electricity
B. gas
C. water
D. telephone
Labor

A. station manager
B. other labor
C. part-time labor

Equipment

A. handling containers (loading, unloading, and transporting)
B. fire prevention
C. accidental contamination
D. safety (clothes, gloves, glasses, etc.)
E. monitoring

Miscellaneous

A. liability insurance
B. other

A building equipped with the necessary facilities to perform collection, accounting, and storage functions will be required. The operation of the station will require a full-time manager and possibly other full-time labor as well as part-time labor during peak periods. Loading equipment, special clothing and other safety items may be necessary for efficient and safe operation of the station.

Transportation

The movement of pesticide containers from farms to final detoxification will be completed in two phases: movement from farms to local county collection stations and movement from collection stations to detoxification plants.

Requiring each farmer to return his pesticide container(s) to a collection station means he will incur an additional cost—a cost not only of expenses associated with actual transportation but
also an opportunity cost of the farmer's time. Although containers must be turned in within some specified time period, this plan is designed to give each farmer as much freedom as possible in selecting a convenient time. Possibly other activities which would require a trip to the county seat can be conducted when returning pesticide containers, thus minimizing this cost somewhat. Freedom to select an appropriate time for turning in containers and convenience of the collection station should encourage voluntary participation and reduce the amount of regulatory activities.

The major bulk of container handling and transporting will occur in moving containers from collection stations to detoxification plants. Containers will be loaded on trucks specifically designed to insure against any pesticide contamination and transported to the appropriate detoxification plant. Each detoxification plant will be equipped with the necessary facilities to handle and store containers while awaiting incineration.

Costs associated with this phase of container transportation will depend on the number, type, and size of containers within the state and the frequency of pick-up intervals at collection stations. Special equipment and procedures to prevent accidental spills of containers during transit could result in significant increases in container transportation costs versus conventional product transportation costs.

Scheduling pick-up intervals at each station may allow one truck to serve in transporting containers from many stations in several areas or districts. The central office will coordinate
pick-up activities. Trucks would likely be based at strategic points throughout the area.

Some items of cost involved in operating large trucks associated with this phase of transportation of containers are:

**Truck costs** truck equipped to specifications

**A.** fixed cost
1. depreciation
2. interest
3. license and taxes
4. insurance

**B.** operating cost
1. truck driver
   a. salary
   b. insurance
   c. miscellaneous
2. fuel
3. tires
4. maintenance (oil, lubrication, repairs, etc.)
5. miscellaneous

**Detoxification**

Detoxification, the final phase in decontaminating pesticide containers, involves the establishment and operation of detoxification plants. The detoxification process might best be understood by considering the process used, operation of the plant, and possible requirements.

Detoxification is assumed to be accomplished by an incineration process, although some chemical treatment may also be involved. Containers might require shredding to reduce container storage area and also to assure more complete detoxification (30). Incineration of these pesticides will produce several toxic gases. The incinerator must be equipped with a scrubber which employs chemicals and/or...
mechanical devices to trap these gases, thus insuring that they will not be discharged into the environment \( (2) \). After incineration, the toxic gaseous effluent, scrubbing materials and incineration residues will be disposed of in a sanitary landfill.

The operation of the detoxification plant will therefore involve temporary storage of containers, incineration of containers, and finally, disposal of residues. Each phase of detoxification may require specialized labor and equipment. To insure that all containers are accounted for as they move through the detoxification system, records must be kept on containers decontaminated.

Plant size will depend on the number, type, and size of pesticide containers in the area served by each plant. An estimate of the present number, type, and size and of the expected future number, type, and size containers for each county is needed before any recommendations can be made as to the size and number of detoxification plants needed to detoxify farm pesticide containers within the state. Although economics associated with plant size are expected, transportation cost will increase as plant sizes are increased and must be considered, as well as per unit plant cost, in selecting the size and location of the plant for a particular area.

The possibility of contamination to the area surrounding the detoxification plants may be a problem and, therefore, requires an isolated location. Avoiding possible contamination would probably require continuous monitoring of the immediate atmosphere and surrounding area. Other precautionary considerations discussed for
collection stations, such as management and long term use of the land area, would apply for detoxification plant locations.

Physical facilities for detoxification plants may be somewhat similar to those required for collection stations. However, a larger building and land area will be required because of the incineration and landfill operations needed for detoxification. The operation of the plant may require highly trained technicians, large equipment operators, and possibly some part-time labor during peak periods. Special equipment will be needed to handle containers within the plant as they move through each phase of incineration. Other specialized equipment will be required to handle incineration residues and transport these residues to the landfill site. Heavy earth-moving equipment will be used in the sanitary landfill operation.

A more detailed list of possible requirements follows:

**Land**  a fence plant site

**Building**  a shed-type building with adequate space for specialized areas

A. receiving containers  
B. storage  
C. incinerator  
D. office

**Utilities**

A. electricity  
B. gas  
C. water  
D. telephone

**Labor**

A. plant manager  
B. technicians  
C. heavy equipment operators  
D. other labor  
E. part-time labor
Supplies

A. chemicals
B. scrubbing agents

Equipment

A. handling containers (loading, unloading, and transporting)
B. transporting residues
C. earth-moving equipment
D. accidental contamination
E. safety (clothes, gloves, glasses, etc.)
F. monitoring

Miscellaneous

A. liability insurance
B. other

Management

A pesticide detoxification system, like any business firm, government agency or other entity, requires a management or decision-making unit. A management office will coordinate and supervise all the activities of the pesticide detoxification system.

The organizational structure and operation of the pesticide detoxification system will depend to a great extent on the number, type, size and especially the location of pesticide containers within the area under consideration. Initially, the present and expected future number, type, size and location of pesticide containers will influence the physical facilities and operational requirements within each county as well as the structure of the entire system. Assuming that the most efficient structural organization of a detoxification system is established for Mississippi, efficient
operation of this system is dependent on the delivery of the anticipated supply of containers. Unlike the marketing of agricultural products, pesticide users have little incentive to transport pesticide containers from farms to local collection stations. In this example, it is assumed that a law will be enacted requiring all containers to be turned in at collection stations. However, all laws and regulations require enforcement. Effective enforcement will require some type system to identify those who comply with, and those who ignore the law. Accounting for all containers from initial packaging to final detoxification will generate the data needed in developing a program to encourage the turning in of pesticide containers as well as identifying those who ignore the law. Securing the necessary information from firms who manufacture and market pesticides may require additional regulations.

The flow of pesticide containers from farms to collection stations will likely be sporadic and seasonal. Operational costs of the detoxification system may be significantly influenced by such variability. By accounting for all containers, estimates of expected volumes at each collection station can be calculated. These estimates along with reports from all facilities should provide much of the information needed for planning and coordinating all the activities associated with collection, transportation, and detoxification in an efficient manner.

The on-going process of managing the pesticide detoxification system may be divided into two groups of activities. One group
Figure 1. Schematic Diagram of Pesticide Container Flow, Accounting System and Management of the Pesticide Detoxification System.
deals mainly with assimilating data for management decisions. These activities include analyzing reports and accounting for all containers along with a mail-out program to remind and notify pesticide users to turn in containers. The other group of activities involves management decisions concerning the day-to-day operation of the detoxification system. A schematic diagram of the flow of information for overall management of the detoxification is presented in Figure 1.

Accounting system.—It is assumed that a computerized accounting system will be established to account for containers as they move through marketing channels. Manufacturers of final pesticide products might be required to package pesticides in resealable containers. Each container will be identified so that the appropriate information can be submitted to the accounting office when a sale is completed. Pesticide manufacturers will be required to keep records as to where and to whom each container was sold and shipped. This requirement will also apply to all pesticides entering the state. Each subsequent change of ownership as containers move through marketing channels will require forwarding of similar information to the accounting office.

Records of pesticide purchases from all retail sources will also be required. At the time of purchase, pesticide users will indicate the collection station to which they anticipate delivery of containers. The accounting office will accumulate records of containers to be returned to each collection station. Such information will be required in order to insure that all containers are collected and
detoxified. When the farmer returns the container(s) to the collection station, notification of the delivery will be forwarded to the accounting office.

Management decisions.—Accounting data and reports from all stations should provide much of the information needed for making efficient decisions consistent with minimizing the cost of operating the detoxification system. Transportation efficiencies may be realized by more effective routing and dispatching of trucks. Labor and other operational costs might be reduced by more efficient planning. Estimates of expected container volumes will serve as a useful guide for operating some facilities on a part-time basis when most containers have been turned in.

In the long run, factors influencing pesticide use may change, thus requiring changes in the organizational structure of the detoxification system. Having accounted for all containers, a complete historical record of pesticide use will be available for analyzing and planning any possible changes. A computerized accounting system will likely be an essential tool for managing the pesticide container detoxification system.

An Approach for Estimating Pesticide Container Detoxification Costs

The conceptual model presented outlines the main elements of costs and variables which influence the costs of detoxifying pesticide containers. Many other factors, functions, and sub-
functions which influence the costs associated with each phase of detoxification are revealed only when detailed detoxification plans are developed. However, whether pesticide containers are detoxified by a government agency or whether a system of returnable pesticide containers is used or some other system is developed to prevent the discarding of pesticide containers into the environment, essentially the same basic functions must be performed in each case. Therefore, the model offers a great deal of flexibility for developing and considering numerous alternative detoxification systems.

An economic evaluation of alternative systems would provide the decision inputs needed for selecting the system which would tend to minimize total detoxification cost as well as meet other policy considerations. Because of the limited information available, cost estimates cannot be made at present; however, current research techniques are available, or can be modified, to estimate the tangible costs associated with detoxifying pesticide containers.

The hypothetical detoxification system presented is only one of many possible systems; however, it serves as a useful guide for briefly considering cost estimation procedures and minimization techniques for evaluating this system.

First, two areas of basic data must be developed: (1) the number, type, size, and location of pesticide containers by county and for the entire state and (2) explicit specifications for collection stations and detoxification plants.
Information on container volumes and location may be obtained by using various sampling procedures, selected area surveys, farm budgets, cropping and livestock patterns, and possibly initiating some type accounting system similar to the one described in the management section. Once present usage patterns have been developed, projections (using regression and related techniques) can be made for various future time periods.

When explicit specifications for collection stations and detoxification plants have been developed, an economic engineering or synthetic firm approach could be used to evaluate alternative size of stations and plants. Results from such analysis would permit the selection of the most efficient size collection station to handle the containers within each county from those alternative sizes considered.

Estimates of the cost of transportation by county could be calculated once the volume of containers from each county is known. Transportation costs between selected points could be established and, using collection stations as supply points, a transportation type model could be adapted to evaluate various arrangements of numbers, sizes and locations of detoxification plants in determining the arrangement which tends to minimize costs of collecting, transporting, and detoxifying all the pesticide containers within the state.

Estimates for other areas of cost, such as the cost of transporting containers from use locations to collection stations, the cost involved with marketing firms providing accounting and related data, and the cost of operating the accounting system, as well as
other costs involved with management of the entire detoxification system, must be developed to determine the entire cost of detoxifying pesticide containers.

Methods and procedures for estimating the cost of transporting containers to collection stations can be gleaned from sanitation studies, milk collection and delivery studies, and other studies associated with transporting various agricultural products. Computer service agencies could be contacted to determine the charges for various accounting and mail-out program services. Other management related costs could be estimated from related studies and secondary sources.
SELECTED BIBLIOGRAPHY


