Geography of Hazardous Waste Generation and Management Capacity in Ohio[1]

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Abstract. **Dealing with hazardous wastes is one of the most important problems facing American society today. The technical and planning dimensions of this problem have been the subject of intense study, as well as legislation and regulations. Coming to grips in a concrete fashion with the problems posed by hazardous wastes will also depend on understanding some of the geographic aspects of their generation and management. This paper considers the locations in Ohio where hazardous wastes are generated, in the context of the Capacity Assurance Program (CAP) instituted under the Superfund Amendments and Reauthorization Act (SARA), and suggests some of the factors that will require consideration in order to use the CAP planning process for substantial improvement of hazardous waste management in Ohio.**

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INTRODUCTION

Managing hazardous wastes poses one of the more important problems facing American society at the end of the 20th century. There is a technical dimension to managing these wastes, but there is also a critical planning dimension which cannot be overlooked. In this context, it is crucial to understand how much waste is being generated, where it is being generated, what options for management are available, and what are the implications of waste generation and treatment for the larger society. The geographic factors governing the location of generation and treatment have changed somewhat in the last ten years. Those factors governing generation have always been primarily economic and will continue to be so. Hazardous-waste generators are located in their present locations because they can make a profit by carrying out industrial activities in those locations. Prior to the passage of the Resource Conservation and Recovery Act (RCRA) of 1976, the same was largely true for hazardous-waste management facilities. They were simply industrial activities, and beyond the needs for certain basic resources, such as water, they tended to be located in places where they could make a profit.

This paper examines the current status of hazardous-waste generation and management in Ohio and begins to predict some of the new developments that can logically be expected for facility location. In so doing, it will concentrate on the geographic dimension of both the current situation and the factors that will affect future developments. There are several reasons to do a study of this sort in Ohio. Its industrial mix includes all of the heavy industries typical of the United States, and in many ways it is a microcosm of the entirety of the industrial United States. Its data base describing the generation and management of hazardous wastes is also one of the best in the country (National Governors' Association 1988).

With the passage of the RCRA and especially the Hazardous and Solid Waste Amendments (HSWA) to RCRA in 1984, the standards for locating hazardous-waste management facilities have been tightened considerably, and it has become extremely difficult to locate a new facility anywhere in the United States. Section 104(k) (9) of the Superfund Amendments and Reauthorization Act (SARA) of 1986 mandates that states must certify that they have sufficient capacity to manage the hazardous wastes generated by their industries for 20 years into the future in order to continue to receive remedial action funds under the Federal superfund program. This means, in essence, that long-range planning has become a crucial part of the nation's hazardous waste management program.

Section 104(k) (9) of SARA has led to a significant national planning exercise. In this exercise, called the Capacity Assurance Program (CAP), each state assessed its current and projected generation and management of hazardous wastes using guidelines provided by U.S. EPA, and determined the status of its waste management capabilities. The Ohio study has recently been published (Ohio EPA 1990). The CAP effort saw each state evaluating its situation in a fairly simple way. Geographic variations within the states were not considered; nor were the structure of the interactions between states that would be required in order to enable the location and operation of specialized facilities used to handle particular wastes, so that they would not be duplicated wastefully in all 50 states. Interstate compacts were assumed to be appropriate, but they were more likely to be based on U.S. EPA regions than on other factors that might be more rational.

The basic wording of the law and the fundamental intent of Congress are fairly simple. The U.S. EPA commissioned a number of guidance documents and other resources to help states in making the certification as required by the law. States were required to aggregate all of their waste streams into a statewide total, with the wastes themselves considered in terms of 17 different waste types and management aggregated to 15 generic waste management categories (Table 1). Each of the 17 waste streams was associated with one or more of the waste management categories as being appropriate or preferred ways for managing the waste in question. Capacity is estimated on a facility-by-facility basis for each of these 15 management categories. Each state then had to gauge whether sufficient capacity in the acceptable (i.e., preferred or appropriate) management category was available, either within the state or within the U.S. EPA region

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TABLE 1

Classification of waste and management categories.

SARA Waste Type	SARA Waste Management Category
1. Contaminated soil, sand, and clay	1. Metals recovery
2. Halogenated solvents	2. Solvent recovery
3. Nonhalogenated solvents	3. Other recovery
4. Halogenated organic liquids	4. Incineration of liquids
5. Nonhalogenated organic liquids	5. Incineration of solids and sludges
6. Other organic liquids	6. Energy recovery: kilns, boilers, furnaces
7. Mixed organic and inorganic liquids	7. Aqueous inorganic treatment
8. Inorganic liquids with organics	8. Aqueous organic treatment
9. Inorganic liquids with metals	9. Other treatment
10. Other inorganic liquids	10. Sludge treatment
11. Halogenated organic sludges and solids	11. Stabilization
12. Nonhalogenated organic sludges and solids	12. Land treatment
13. Other organic sludges and solids	13. Landfill
14. Mixed organic/inorganic sludges and solids	14. Underground injection in deep wells
15. Inorganic sludges and solids with metals	15. Other disposal
16. Other inorganic sludges and solids	16. Storage awaiting further management
17. Other wastes	17. Unknown management

Classification from Versar, 1989.

of which it is a part (Office of Solid Waste 1988; Versar, Inc. 1989). States had a certain amount of flexibility with regard to completion of their assessment. Those states with good annual records and experience in handling them were free to use them, even if they include only the materials which were required for reporting by U.S. EPA prior to 1987. Other states were encouraged or required to use the newer, much more detailed, reporting requirements established in 1987. These latter requirements (Office of Solid Waste 1987) make it much easier to identify the form of the waste and, therefore, the degree to which it is amenable to particular kinds of treatment. The guidance documents suggest that states were free to use a rather broad range of mechanisms in calculating their capacity assurance. In fact, the methodology appears to be fairly restricted, and virtually all states could be expected to calculate their waste generation and capacity in essentially identical fashion unless they had individual reasons for exceeding the minimum.

On one hand, this has led to an unprecedented interstate integration of available data; on the other hand, it underscores the potential for improvement in the planning exercise.

The data collected by the Ohio EPA have been self-supplied by generators of hazardous waste and facilities treating those wastes. They exist in two files, one summarizing the data supplied by the facilities and the other summarizing the data supplied by the generators (Dimoff 1989; Ohio EPA 1989; Kelley and Dimoff 1990). The "Generator" file includes the name, address, SIC Code, and contact person for each generator submitting a report, as well as a description of each waste stream generated by that facility, including amount generated, a verbal description, and U.S. EPA hazardous waste code. The "Facility" file includes much the same information, except that the information describing the facility refers to that receiving the waste, not to the generator.

The Ohio EPA data base has been generated using the old U.S. EPA data requirements. That is, it does not require detailed description of the form of the waste stream as mandated for the 1987 report forms, although it does require the reporting of generator SIC codes, which the federal forms prior to 1987 did not. The CAP analysis was based on these data, so that the precision of the allocation of individual waste streams to the 17 SARA waste categories was relatively low. On the other hand, the fact that the Ohio data base includes information about generator SIC codes makes it possible to perform certain kinds of planning which are not possible using older federal forms, and the fact that the Ohio data base has been stable for several years means that time trends can be prepared and compared for questions other than capacity assurance.

The data are not perfect. They are, after all, supplied by individual generators and facilities, and they are only as accurate as these reports. It is all but impossible for Ohio EPA to insure that the data it receives are precisely correct, or that they have received all the reports that are required under current law. Inconsistencies between the data sets suggest that some generators which should report, fail to do so. Generators are subject to much less regulatory scrutiny than management facilities, and OEPA believes that the data from the facilities are correspondingly far superior to those from the generators. Nevertheless, it is not clear that the data supplied by facilities is inspected by OEPA personnel to the same degree that the facilities themselves are inspected. Even when a particular waste stream appears in both the Facility and the Generator file, the amounts do not always agree. This implies no criticism of the Ohio EPA; data of this sort are always subject to this kind of problem, and it is doubtful that the data base could meet any rigorous standard for precision or accuracy or completeness. At best, the data are uneven, and they should not be taken as much more than a good approximation of the actual flows of waste materials. In any case, they are the only data base that exists for these wastes, and they are sufficiently precise to allow certain conclusions to be drawn.

The Ohio CAP report (Ohio EPA 1990) concludes that the state has the capacity to manage its wastes in the future with minimal problems. However, it bases this conclusion on assumptions such as a 50% reduction in hazardous waste generation per unit of production and interpretations of the data based on national averages. It does not use all of the information available in the data base, and it limits its scope to a particular set of questions set forth in the guidelines issued by U.S. EPA. One can certainly question the assumptions, and it is very meaningful to go beyond the particular questions that formed the basis of CAP. Most prominently, the logic of CAP assumes implicitly that waste management capacity is to be met by existing facilities. Almost all of these facilities (i.e., those that were not permitted after 1976 as new facilities under RCRA, and very few major facilities have been so permitted) are currently operating under "interim" permits that are less demanding than the "final" permits required for new facilities. All facilities will have to be brought up to "final" standards over the next few years, but it may well be that some facilities being depended on currently will be unable to meet the more rigorous "final" standards. Even if they can meet these requirements, it is reasonable to believe that new facilities originally designed to meet the standards set forth in RCRA and state implementing legislation will be preferable to older facilities, both environmentally and economically. Thus, CAP cannot deal with replacement of older facilities with newer ones, even though we can expect this to be highly desirable, and states will need to consider this likelihood in their ongoing regulatory and planning functions.

The greatest strength of the approach mandated by U.S. EPA for CAP is the aggregation scheme for both waste types and treatment methods. These are essentially the categories developed by ERM, Inc. in analyses of several states' hazardous waste systems over the last few years (e.g., ERM-Midwest 1985). Although one can always find room to question the categories chosen, the waste categories reflect real differences among wastes that affect their treatability, and the treatment categories constitute an industrially meaningful classification. Previously, wastes were identified only by several hundred four-digit waste codes, and management techniques by 74 three-digit management codes (EPA 1980). These codes may have made sense in identifying waste streams for regulatory purposes early in the RCRA program, but they were too abstract to be very useful for practical planning purposes.

Unfortunately, it is not a trivial job to allocate waste streams described in terms of the 4-digit U.S. EPA waste codes to the 17 SARA waste types. The U.S. EPA provided a table, based on national profiles, which shows the breakdown of each EPA code into the 17 waste types (Appendix C in Versar, Inc. 1989). States were instructed to use this conversion unless they had a better mechanism. It is doubtful that many states used an alternative approach, since using this matrix is straightforward and does not require justification to U.S. EPA for interpreting the state's CAP results. However, the information in the Ohio data base provides a better way to make this allocation than the U.S. EPA-supplied conversion table. Ohio EPA chose to use the table, but believes that the errors introduced into the analysis in the process cancel each other, so that they are insignificant in their impact on the calculation of needed statewide capacity for preferred treatment types. This is likely to be the case, but more focused methods of allocating individual waste streams to the 17 SARA waste types will be required if more detailed planning or assessment of the situation in the state is to be carried out.

A number of detailed planning questions come to mind. For example, what facilities are likely to close over the next few years? What industries and waste streams did they serve, and how will their closure reverberate through the system, both geographically and with respect to individual generators? This is especially important with regard to large commercial treatment facilities such as secure landfills. Also, where should new facilities be located, and what kinds should they be? What industries should new facilities be intended to serve? What kinds of facilities are needed and why? Need is related to capacity and the use of that capacity, and states vary considerably. Some states do not have adequate capacity within their own borders (for example, Wisconsin has no hazardous waste treatment or disposal facility anywhere within the state). Others, notably Maryland, have sited new facilities, only to have them close because the market would not bear the prices that they were forced to charge in order to cover their costs.

Perhaps even more significant—and less precisely understood—is waste reduction. The simplest way of considering waste reduction is the actual reduction of waste generated, as discussed by the Office of Technology Assessment (OTA 1986) and INFORM (Sarokin 1985). The U.S. EPA has done a very detailed survey of representative manufacturing industries to determine what actual reductions are likely to take place (EPA 1986a,b). Some of the results of this EPA study are referenced in the technical reference manual for the capacity assurance program (Appendix A in Versar, Inc. 1989).

One cannot reliably assume statewide average rates of waste reduction for particular industries. Waste reduction requires some change in the way a process is carried out in an individual plant. Either a process within the plant must change, or the degree of recycling of wastes produced by particular processes must increase. All definitions of waste reduction include the former; not all include the latter (OTA 1986, EPA 1986a). But the possibilities for change on a plant-by-plant basis are affected by plant design and management, and they are very sensitive to a broad range of factors. Several studies have pointed out how waste reduction is economically rational for many companies. However, manufacturing plants which would make the changes that would accomplish waste reduction must have sufficient lifetime remaining to warrant the investment. They must have management at plant and corporate levels with the capital and the inclination to make the change. Without strong mandate in the form of legislation, the progress of waste reduction will be much more erratic than that of most foreseeable changes in the hazardous waste management system as a whole. Some plants will upgrade much faster than others; others will upgrade much more slowly.

These observations reflect the notion that hazardous waste management is a system, and that both generators and treatment/storage/disposal facilities interact in a dynamic context. Both the geographic and economic dimensions of this context are significant, and one might reasonably want to understand the implications of various changes in economic terms or geographic terms as much as by the simpler notions of "need" or "capacity."

The statewide highly aggregated approach used by CAP is the obvious place to begin a detailed analysis of the future needs of a state's hazardous waste management system. But it should quickly move to a more focused level if it is to have a real role. "Focus" in this context refers both to particular facilities and to their locations. Different industries have different problems, and different regions have specific resources and limitations when dealing with hazardous wastes. The Ohio data base allows the next step to be taken. The four-digit SIC code for the generator is an adequate indicator for industry, and geographic location can be indicated either by county or zip code. Type of management used also needs to be indicated. Ohio has long included the first two pieces of information in its Annual Reports, as does the new 1987 Federal biennial report form. Management technique appears in the Facilities file, and so is known for all waste streams that are treated within the state. Two pieces of useful information currently required by neither Ohio nor U.S. EPA would be for the Facilities file to report the SIC code number of the generator of each waste stream and for the Generator file to indicate management technique applied.

MATERIALS AND METHODS

Wastes can be generated within Ohio or out-of-state. They can be managed on the site of generation, in an off-site facility, or sent out-of-state for management. Four combinations of these site-of-generation and site-of-management appear in the Ohio EPA records (Table 2). To perform the analysis in this paper, the Generator and Facilities files were combined into a single file comprising all of the information about hazardous waste generation and disposition in the state of Ohio contained in the Ohio EPA 1987 Annual Report data base. This was a two step process: concatenating the two files and then removing double records and improving the information content of each record. One of the four combinations (Table 2) logically results in waste streams being double-counted in the concatenated data base: those generated within the state (and hence appearing in the Generator file) and treated in a commercial facility (and hence appearing in the Facilities file). Wastes treated on the site of generation appear only in the Facilities file; those sent into Ohio from out-of-state likewise appear only in the Facilities file; those generated in Ohio and sent out-of-state for management appear only in the Generator file. Each case can be recognized from the facility and generator identification numbers. Waste streams with no double-counting were left in the concatenated data base without change, except to set the SIC code to "0000" if the generator's SIC code was not known, and the county to "00" if the waste came from out-of-state.

Removing the double-counted records was reasonably straightforward. When the Facilities file indicated the ID number of the generator (some did not, for reason of confidentiality), the data base was sorted so that individual waste streams were paired, one from the Generator file and one from the Facilities file. Where pairs were found, the management technique was accepted from the Facilities file, and the county of origin and SIC code were accepted from the Generator file, leaving a single record with all available information. Sometimes, agreement on description and amount were exact; more often, they were somewhat different. In the latter case, the larger number was the one that was accepted. It also became clear that a number of facilities reported receiving wastes from a number of generators who had not reported sending the waste. In this case, the volume and description of the waste was accepted from the Facilities file, a county of origin was identified from the generator's address, and the SIC code of the generator was recorded as 0000. Occasionally, a generator reported sending wastes to a facility, but there was no corresponding record of the receipt of that waste in the Facilities file. In this case,

TABLE 2

Identification of waste flow types from Annual Report *data.*

Type of Waste Flow	Source File for Data		EPA ID Number Prefix		Status of EPA ID Numbers	Double Counted
	Generator	Facility	Generator	Facility		
Generated Out-of-State Managed In Ohio	No	Yes	not OH	OH	Different	No
Generated In-State Managed at Ohio Commercial Facility	Yes	Yes	OH	OH	Different	Yes
Generated In-State Managed On-Site	No	Yes	OH	OH	Same	No
Generated In-State Managed Out-of-State	Yes	No	OH	not OH	Different	No

the amount and description of the waste were accepted from the Generator file, with the treatment code being listed as U00. The county of origin and SIC code were also accepted from the Generator file.

Nine facilities provided no information about their customer list. All generators reporting that they had sent wastes to these facilities, as well as records indicating receipt of wastes by these facilities, were sorted by the amount and description of waste. When a waste stream from the Generator file was found with the same (or nearly the same) waste description and amount as a record from the Facilities file, the assumption was made that the records in question could be equated. The county of origin and SIC code were accepted from the Generator file, along with the treatment from the Facilities file. This was sometimes fairly straightforward if the amounts and descriptions agreed precisely. More often, agreement was not precise. One cannot represent that every pair equated through this process originally represented precisely the same waste transfer. But it is clear that each record represents the transfer of some material. Thus, equating two records, one from the Generator file and one from the Facilities file, at least reduces the error in the data base. Any error which remains results from the asymmetry in the original data and cannot be eliminated altogether. Through this process, the degree of unpaired data was reduced by over 90%. As before, the SIC code and county of origin were accepted from the Generator file and the treatment accepted from the Facilities file; if the agreement was approximate, then the larger of the two amounts that were accepted as being a plausible pair was used. Those records from the Generator file which could not be plausibly identified with a record from the Facilities file had treatment types listed as U00; those records from the Facilities file which could not be plausibly associated with a record from the Generator file had county of origin and SIC code listed as 00 or 0000, respectively.

Once the single data base was constructed, each waste stream was allocated to one of the 17 SARA waste types, and those records including treatment types were allocated to one of the SARA waste management categories. In order to ascribe SARA waste types, each record was examined in detail, and judgments were made about its content. The information about the waste stream provided in the data base consisted of one or more four-digit EPA waste codes and the verbal description of the waste. Table C1 of the CAP Technical Reference Manual (Versar, Inc. 1989) also provided insight into the categories into which a particular waste stream was likely to fit. It was a time-consuming but generally straightforward process to associate each record with a SARA waste type. It was much easier to relate the 15 SARA management techniques to the three-digit EPA treatment codes found in the data base. In addition to these 15 techniques, "Storage" and "Unknown" are also included, where the management technique is reported in the data base as storage or where no management technique could be associated with the record. Ultimately, the final data base included not only the information provided by Ohio EPA, but also the SARA waste type and management technique for each record (Table 3).

RESULTS AND DISCUSSION

Ohio is an industrial state. Virtually all parts contain heavy industry, and 87 of the 88 counties have generators reporting hazardous waste production in 1987 (Fig. 1). Almost 3.5 million tons of hazardous waste appears in the Annual Report data base for 1987, and its generation is widely distributed.

Contaminated soil (Fig. 1a) accounted for 22,220 tons of the state's total hazardous waste flow in 1987. The state's major industrial areas produced the majority of this waste type, but some less industrial areas produced more than might otherwise be expected. Presumably, this is because at least some contaminated soil represents non-recurring problems only indirectly related to industrial production. The overwhelming majority of these wastes were disposed of in secure landfills. Spent solvents accounted for 90,661 tons of waste generated in Ohio in 1987 (Fig 1b). They came from virtually every county. As expected, the greatest contribution comes from the major industrial cities such as Cleveland, Dayton, and Cincinnati, but significant contribution also comes from counties containing large "greenfield" manufacturing plants. Some of these counties are quite rural except for these industrial facilities. The overwhelming majority of spent solvents were reclaimed or burned, either in incinerators or in energy-recovery facilities. Other organic liquids (Fig. 1c) accounted for 34,900 tons of waste in 1987. Their distribution is similar to that of the solvents, except that contribution of these wastes was more closely associated with the state's major industrial areas, notably Cleveland, Lorain-Elyria, Columbus, Dayton, and Cincinnati. Again, most of these wastes were reclaimed or burned. Liquid wastes consisting of mixed organic and inorganic components (Fig. 1d) accounted for 56,107 tons in 1987. They were also concentrated in the state's primary manufacturing counties, except for Allen County in northwest Ohio and Scioto County in south-central Ohio, each of which includes one major plant producing these wastes. Except for the plant in Scioto County, which has an on-site injection well, these wastes tended to be burned or treated, depending on their organic content. The largest of the state's hazardous waste streams was inorganic liquids (Fig. 1e), with 2,321,329 tons of these wastes produced in 1987. They came from almost every county, but they were concentrated in those counties with major metals, petroleum refining, and basic chemical industries. Those companies with on-site injection wells managed these wastes by deep-well injection; most of the remaining waste was treated in aqueous treatment plants. Ohio produced 52,008 tons of organic sludges and solids in 1987 (Fig. 1f). They were concentrated in the counties bordering Lake Erie, and in the corridors along Interstate 75 in southwestern Ohio and U.S. 23 in south-central Ohio. Most of these wastes were burned, although a sizeable fraction was recycled or stored, presumably for recycling.

Sludges and solids consisting of mixed organic and inorganic wastes accounted for 121,049 tons of waste produced in Ohio in 1987 (Fig. 1g). They were broadly distributed, both from the counties containing the state's major manufacturing cities and from counties containing one or more "greenfield" plants. Treatment was extremely

TABLE 3

Summary of hazardous waste generation and management in Ohio, by SARA Category.

Waste Type	Waste Management Category																	Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
1	0.0	0.1	0.0	0.0	31.6	34.9	19.0	0.0	0.0	1.6	86.3	0.0	8334.0	0.0	0.0	16.1	13695.9	22219.5
2	0.0	13010.7	0.0	788.2	99.0	11060.1	540.5	5.3	532.4	6.6	10.7	0.0	1.2	0.0	0.0	1062.7	3233.1	30350.5
3	0.0	29871.2	0.3	1151.4	1228.7	4049.5	456.0	0.0	588.6	3.0	44.4	0.0	22.7	0.0	0.0	2067.6	20827.0	60310.4
4	0.0	98.0	0.0	52.1	1.6	0.0	16.7	0.0	58.1	0.0	160.4	0.0	0.0	0.0	0.0	2.1	1515.0	1904.0
5	0.0	9315.4	0.0	1982.3	54.8	1463.0	196.9	1.0	243.6	5.3	149.6	0.0	31.5	0.0	0.0	3254.1	2706.0	19403.5
6	0.0	1855.9	0.0	874.3	50.9	6837.7	2374.3	5.8	231.1	0.0	37.7	0.0	15.7	0.0	0.0	294.9	1014.6	13592.9
7	0.0	5491.9	4.3	13020.5	4206.4	1535.9	298.3	0.3	8181.1	29.8	160.4	0.0	59.8	19071.0	0.0	3157.0	889.8	56106.5
8	0.0	179.8	0.0	618.2	0.0	6312.5	7106.0	28658.0	163.4	0.0	1731.0	0.0	1.0	1005353.0	0.0	3153.7	1.4	1053278.0
9	1066.9	74.0	2.6	78.6	410.7	5.7	64475.6	19062.7	266941.8	5.3	1875.9	4.2	42880.1	358761.2	0.0	20247.9	29834.3	805727.5
10	0.0	40.3	0.0	1497.1	19.8	40.7	15425.6	0.0	397490.7	8.0	166.4	0.0	489.9	35240.0	0.0	1363.3	10541.3	462323.1
11	0.0	1107.6	0.0	2852.5	167.4	2401.8	9.1	0.0	207.8	11.8	72.0	0.0	246.4	0.0	0.0	3263.5	7643.7	17983.6
12	15.1	6362.8	0.0	9512.8	5263.2	1931.7	244.5	0.0	86.4	37.2	528.9	0.0	1034.8	0.0	0.0	2156.0	6087.5	33260.9
13	0.0	19.2	0.0	85.3	14.2	22.7	17.8	0.0	4.6	1.4	17.8	0.0	8.5	0.0	0.0	7.9	563.9	763.3
14	0.0	1572.4	0.1	6817.7	22819.4	423.5	2142.5	1.6	6804.4	1357.0	16153.1	5272.0	29633.4	0.0	0.0	17486.7	10565.0	121048.8
15	251.5	4.4	3.8	673.2	65.9	42.1	9104.0	0.0	4261.3	7975.9	32800.0	0.0	410194.1	0.0	0.0	228953.7	45895.1	740225.0
16	32.0	0.0	2.4	56.3	24.6	0.0	149.4	0.0	10222.9	0.0	201.3	0.0	453.3	0.0	0.0	38.4	544.6	11725.2
17	2.4	44.4	0.0	1108.9	125.2	17.5	3.7	0.0	42.9	2.1	36.2	0.0	158.6	0.0	0.0	84.1	121.3	1747.3
Total	1367.9	69048.1	13.5	41169.4	34583.4	36179.3	102579.9	47734.7	696061.1	9445.0	54232.1	5276.2	493565.0	1418425.2	0.0	286609.7	155679.5	3451970.0

Data from 1987 Annual Report; numbers for Waste Management Categories and Waste Types refer to numbers given in Table 1. All amounts are given in tons.

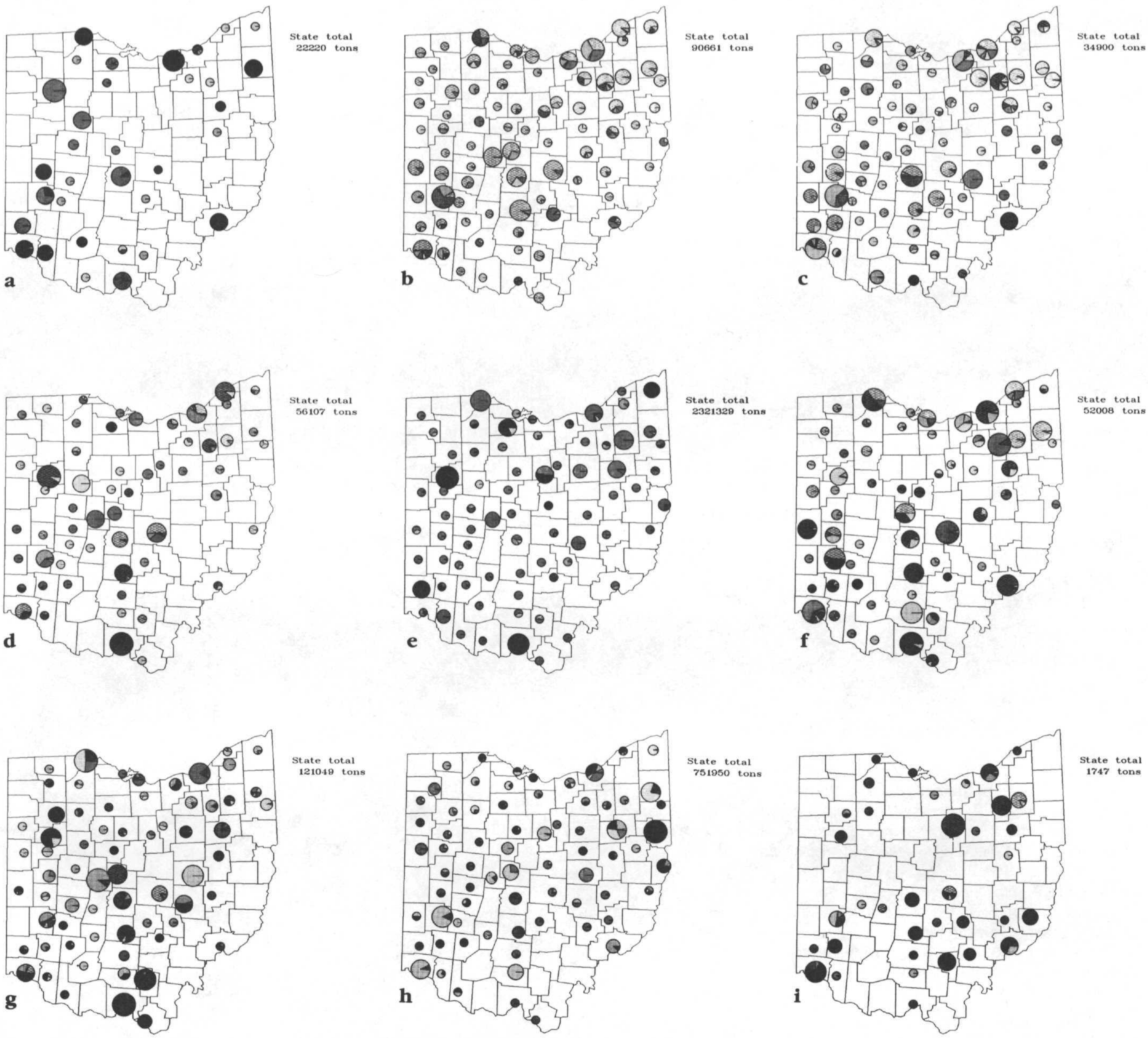
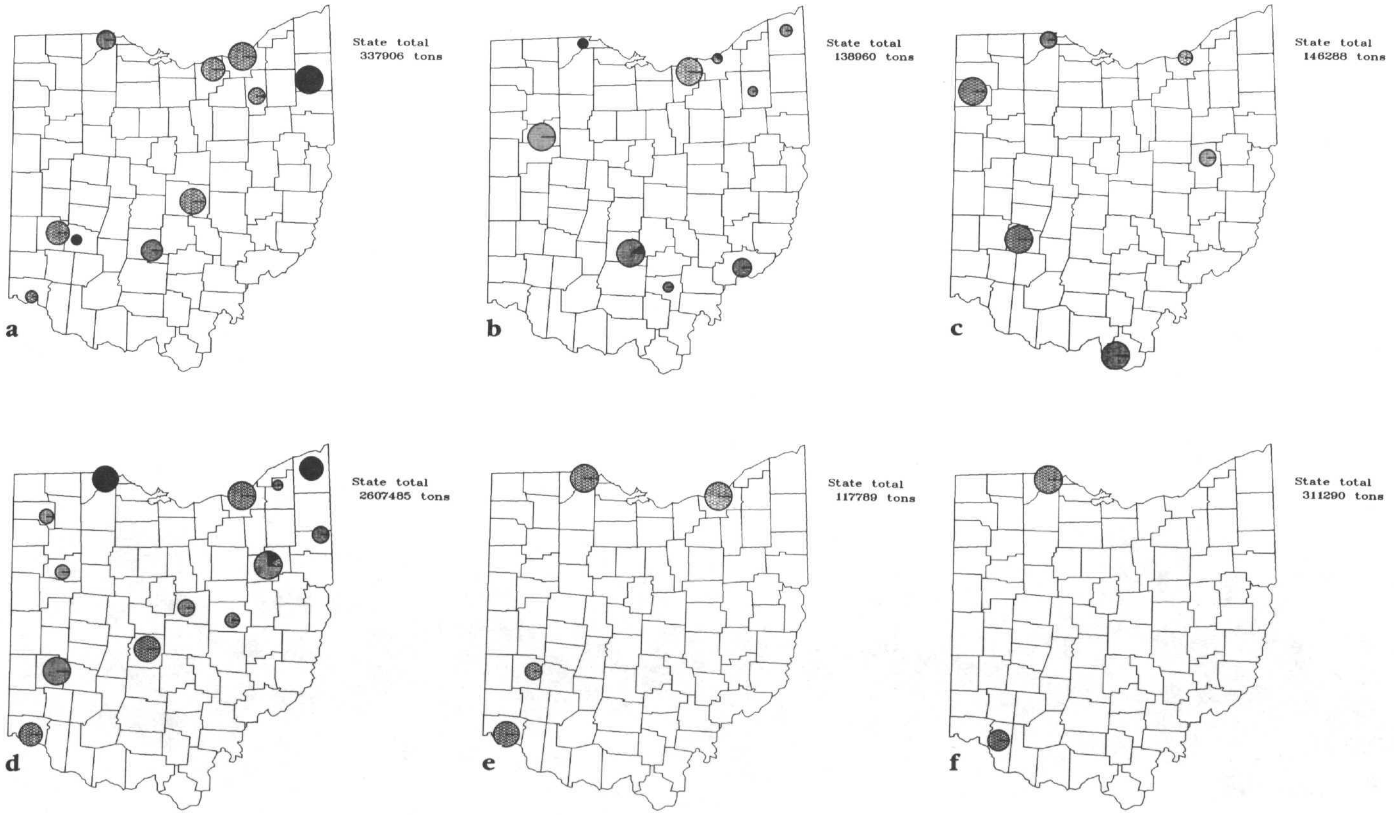


FIGURE 1. Patterns of hazardous waste generation and management in Ohio for 1987. Each map represents one of the following SARA waste types: a) Contaminated Soil; b) Solvents; c) Other Organic Liquids; d) Mixed Organic and Inorganic Liquids; e) Inorganic Liquids; f) Organic Sludges and Solids; g) Mixed Organic and Inorganic Sludges and Solids; h) Inorganic Sludges and Solids; i) Other Wastes. The size of the pies centered in each county seat indicate the relative generation of waste in that county. The pattern of the pie summarizes the management of those wastes in terms of SARA management categories.

variable, although most was either landfilled directly or treated, presumably for subsequent landfilling. The largest component of the solid hazardous waste was inorganic sludges and solids (Fig. 1h), with 751,950 tons produced in 1987. Almost all counties in Ohio produced these wastes, but the largest concentration was in those counties with a lot of activity in the primary and secondary metals industries. Most of these wastes were either landfilled or stored, presumably for subsequent landfilling. "Other" wastes accounted for only 1,747 tons in 1987 (Fig. 1i). This is a catch-all category, and no pattern to its generation is either obvious or would be expected.

Management capacity is much more narrowly distributed than waste generation (Appendices M, N, and O in Ohio EPA 1990) (Fig. 2). The data for management capacity are basically those presented by Ohio EPA (1990), with two exceptions. Facilities known to be closing before 1991 were not considered, and the annual



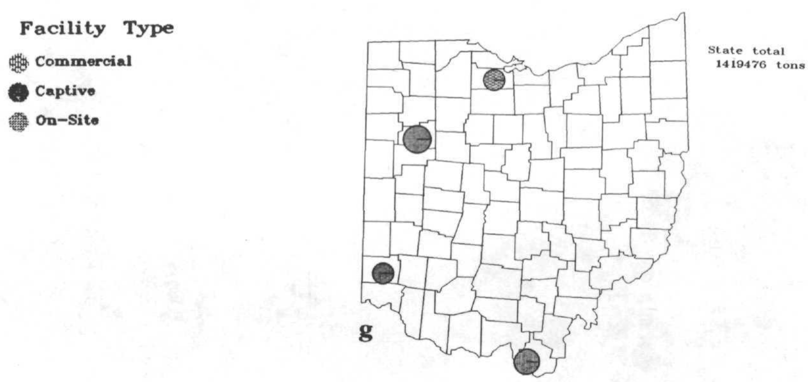


FIGURE 2. Patterns of hazardous waste management facilities in Ohio in 1987. Each map represents one of the following SARA waste management categories: a) Materials Recovery Facilities; b) Incinerators and Thermal Treatment Facilities; c) Energy Recovery Facilities; d) Aqueous and Other Treatment Facilities; e) Sludge Treatment and Stabilization Facilities; f) Secure Landfills; g) Deep-well Injection Facilities
The size of the pies centered in each county seat indicate the relative capacity in that county for the management technique under consideration. The pattern of the pie summarizes the status of those facilities as commercial (i.e., open to all generators), captive (i.e., open to only the wastes produced by the owners of the facility), or on-site (i.e., open only to wastes produced by the facility itself).

capacity for landfills and deep-well injection facilities were assumed equal to their 1987 activity. Management facilities show a strong correlation with the location of the state's major industrial and urban areas, illustrating that their location stems largely from economic factors.

Materials recovery facilities (Fig. 2a) represented 337,906 tons of capacity that were strongly clustered in the state's major manufacturing areas. All of the state's commercial recycling capacity was located within 50 mi of the Cleveland, Columbus, Dayton, or Cincinnati metropolitan area. The captive facility in Trumbull County in northeastern Ohio services the steel industry in the Cuyahoga and Mahoning river basins. The small facility in Greene County in southwestern Ohio is Wright-Patterson Air Force Base, which operates a metals recovery facility to service other Defense Department installations. All other facilities are on-site facilities. The state had 138,960 tons of incineration capacity (Fig. 2b). However, there is only one major commercial incinerator in Ohio. Almost all of the remaining capacity is from on-site incinerators, with a few small captive facilities as well. Energy recovery capacity (Fig. 2c) accounts for 146,288 tons. Energy-recovery facilities are widely spaced, with no clear pattern. This is reasonable, considering that they have something other than waste destruction as their primary business activity. The state had 2,607,485 tons of aqueous treatment capacity (Fig. 2d). Commercial facilities were located in the Cleveland, Canton, Columbus, and Cincinnati metropolitan areas, and captive or on-site facilities were located in a number of other counties. The state's 117,789 tons of sludge treatment and stabilization capacity was located entirely in the Cleveland, Toledo, Dayton, and Cincinnati metropolitan areas (Fig. 2e). All of the facilities of this type are commercial. Ohio had two landfills for hazardous wastes in 1987 (Fig. 2f). Only the one in Oregon, OH, near Toledo, remains open at this time. Finally, the state had four injection wells, which received 1,419,476 tons of waste in 1987 (Fig. 2g). Only the one in Sandusky County is a commercial facility; the other three are on-site facilities.

The state's capacity for handling hazardous wastes was over 5.0 million tons in 1987, compared with total hazardous waste generation of less than 3.5 million tons. This suggests that Ohio has sufficient capacity to meet both current and future needs, so that it does not need to plan for change. This conclusion does not necessarily follow. Of the two landfills in use in 1987 (Fig. 2f), the one in Clermont County in the southwestern part of the state has closed. The other has recently been issued a request for a modification of its operating permit, but that permit is being appealed, and its remaining cell is filling rapidly. As a result, Ohio's long-term secure landfill capacity is substantially less than that implied by the data now available. The significance of this is not yet clear. A significant portion of the state's management capacity is in captive and on-site facilities. These facilities are not available to the majority of the state's generators. A significant portion of the state's management capacity is in the Dayton-Cincinnati area in southwestern Ohio. This is an area of vulnerable groundwater resources, and this vulnerability has been cited as a major problem in the permit renewal and modification of at least one hazardous-waste management facility in Dayton. Although the permit for this facility has been renewed, one of the terms and conditions included in the renewal permit is that the facility must relocate within a few years. The nature of the arguments used in this case suggest that strong pressure may develop for other facilities in this part of the state to move as they enter the permit-modification process. Similar pressure may develop elsewhere. As a result, what now appears to be a substantial cushion in management capacity may disappear over the next few years in response to increased rigor of the permitting process and to the increasing willingness of citizens to fight for the safety of their drinking water supplies. Although Ohio is one of the few states that has proven that it can site a new hazardous waste management facility (Clapham 1990), it is a difficult process that takes a long time.

Other changes may have an even greater impact on the adequacy of the state's management capacity. The RCRA accounts for only a relatively small proportion of the total toxic waste load from the state's industries. More appears in wastewater, which is either pretreated, so that the residual waste is discharged into municipal sewers, or managed according to the NPDES section of the Clean Water Act, so that the residual is discharged directly into surface waters. In either case, hazardous materials removed from the waste-waters are managed as hazardous wastes and appear in the data base used in this paper. Increasing standards for wastewater discharge would lead to a major increase in hazardous waste generation in the state, even if effective waste reduction was being carried out in every industrial facility. We cannot yet project the effect of tightening the Clean Air Act to reduce the emissions of airborne toxics. However, the passage of the Clean Air Act amendments in 1990 will lead to substantial tightening, and any toxic materials that do not enter the atmosphere as a result of this tightening will enter the hazardous waste stream.

A third type of change is suggested by considering inorganic liquid wastes (Fig. 1e). The overwhelming majority of this waste type is treated in aqueous treatment facilities, presumably with the sludge generated during treatment going to secure landfills. The largest proportion of this type of waste comes from the state's prominent primary and secondary metals industries, and many of the waste streams contain materials that can be reclaimed. Yet very little of the material currently goes to materials recovery facilities. The only metals recovery facility in the entire state is at Wright-Patterson Air Force Base, a captive facility dedicated to reclaiming metals from wastes generated within the Defense Department. It does not take a great leap of faith to conclude that Ohio could use some expansion in its metal-reclamation capacity, especially to service the widespread electroplating industry.

If one were to recalculate waste generation and management for the year 2000, one would need to estimate the plant-specific reductions in waste loadings that result from effective waste reduction and increased recycling, and one would have to project the effects of increased hazardous waste generation from tightening of both the Clean Air Act and the Clean Water Act. It is likely that some facilities now in operation will have closed, and very few new facilities will have opened. We do not know where these changes will be, but we can be fairly sure that there will be some pressure to site new facilities for managing hazardous wastes. The siting criteria currently in the Ohio law governing the permitting of new hazardous waste facilities (Ohio General Assembly 1984) also guarantees that the location of new sites will consider the state's water and other geographic resources to a degree unheard of previously.

Unfortunately, there are no answers to the questions raised in this paper. There seems little doubt that the existing balance between generation of hazardous wastes and capacity for managing those wastes allows Ohio at least a window of opportunity to plan to meet future shortfall in management capacity. But the closing of one of the state's two secure landfills and the clearly finite lifetime of the other, coupled with the aging of other existing hazardous waste management facilities, will necessarily bring the need for siting new facilities. This will be the case even with waste reduction on the order postulated in the Ohio CAP report. We are also likely to see increasing pressure to decrease distances of hauling hazardous wastes, since the transportation system has a disproportionate role in releases of hazardous materials into the environment.

In meeting the demand for new hazardous waste management facilities, the state will be guided by one or more of three approaches, which differ with regard to scale. One of the assumptions being made by U.S. EPA appears to be that future facilities will serve interstate regions that correspond to U.S. EPA regions. A second approach is for moderately large facilities that serve a region around 100-200 mi in diameter, and which overlap several states. An example would be the Waste Technologies Industries incinerator now under construction on the Ohio River in East Liverpool, OH. A third approach would be for a smaller facility with a local service area on the order of about 50 mi or so.

There seems to be little support in this part of the country for interstate facilities evidently being envisioned by U.S. EPA. Ohio, in EPA region V, trades considerable quantities of hazardous wastes with regions I, II, III, and IV. The EPA regions may make sense as administrative regions, but they make no sense as economic regions to guide the location of new hazardous waste management facilities. We can anticipate that most of the facilities that will be proposed in the next few years will be either on-site facilities or commercial facilities with service areas less than 200 mi in diameter. This is already true for the permit applications that have come to the Ohio Hazardous Waste Facility Board over the last few years. We can also anticipate that an increasing number of commercial facilities will be local facilities intended to serve concentrations of companies in one or two of the state's manufacturing areas. The experience of the Ohio Hazardous Waste Facility Board indicates that the more local the service area of a proposed facility, the easier it is for that facility to obtain its permit, since it is perceived as a "legitimate" company that does not threaten the populace as much as a larger facility might.

The geographic constraints of siting facilities of these three types of facilities are very different. In principle, one can look for "perfect" geologic and geographic conditions to locate an interstate facility, and other aspects of the location make little difference. A regional facility would have to be located closer to its markets, and it would be much less likely to be located in an area with "perfect" geologic or geographic conditions. For a metropolitan facility, economic criteria would be paramount, and factors of geology or geography would be ignored except as they precluded the construction of this sort of facility.

There is thus a correlation between the scale of a facility's service area and the way in which geographic constraints impinge on it. The practical logistics of the siting process, not only in Ohio but in all industrial states, mean that large-scale facilities will require "perfect" geology and geography in order to meet the applicable siting criteria and thus to obtain their permits. Smaller facilities will need to use engineering, management, and planning to counteract practical limitations of individual sites. The experience of the state's hazardous waste facility siting process over the last decade suggests both that no place exists in Ohio with sufficiently "perfect" geology to locate a very large facility, and that engineering and management can, in fact, counteract the hazards posed by the limitations of potential sites that do exist within the state for local and regional facilities.

The Ohio CAP report (Ohio EPA 1990) is an excellent first step in planning to improve the state's hazardous waste management situation. But logic of its statewide summary is that future solutions to shortfall in management capacity is likely to be met with interstate facilities. If more local facilities are relatively more important than these, then effective planning will require much greater attention to the distribution of generation, existing capacity, resources, geologic and geographic limitations to potential sites, and future change.

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